ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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See half-page Advertisement page 62, Oct. 6.

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Tenders, made out on the Company's Forms, should be delivered, under sealed cover, endorsed "Tender for Old Materials," to the undersigned not later than Ten a.m. on Thursday, the 23rd November, 1916.

The Directors do not bind themselves to accept the highest or any Tender.

T. MORRISON,
Secretary.

Secretary's Office,
Amiens Street Terminus, Dublin,
3rd November, 1916. F 439

CITY OF NOTTINGHAM.

The Works and Ways Committee are prepared to receive

Tenders for the Supply of the undermentioned STORES and MATERIALS. The Contracts to commence on the 1st January next, and to terminate on the 31st December, 1917:—

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(R.) Refined Tar.
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Forms of Tender may be obtained on applying to Mr. ARTHUR BROWN, M.Inst. C.E., City Engineer, Guildhall, Nottingham, on payment of a deposit of 5s. each, which will be returned on receipt of a *bona fide* Tender, in accordance with the specifications, providing such Tender is not withdrawn, and is delivered by the time stated below.

Patterns and Samples may be inspected at the Eastcroft Depot, London Road, Nottingham.

The Committee will not consider any Tender except on the authorised Form of Tender, which must be delivered to the undersigned, in the official envelope provided, on or before Thursday, 30th November, 1916.

The lowest or any Tender will not necessarily be accepted, and Tenders will only be accepted from persons who conform to the conditions as regards paying the local standard rate of wages, &c., and to the working rules of the Nottingham District applicable to the various trades.

By Order,
W. J. BOARD, Town Clerk.

Guildhall, Nottingham,
10th November, 1916. F 455

APPOINTMENTS OPEN.

British Municipal Council, TIENTSIN, NORTH CHINA.—The Council is prepared to receive APPLICATIONS from British subjects for the POST of MUNICIPAL ENGINEER. Candidates will be required to pass a medical examination as to their physical fitness for the position.—Applications should state age, qualifications, salary required, &c., and should be forwarded, together with copies (not originals) of testimonials and particulars of previous employment and experience, on or before December 31st, 1916, to F 449, Offices of ENGINEERING.

General Manager, Engineer, REQUIRED immediately, for a very large engineering works in the South of England, employing 3500/4000 hands. Must be capable of taking over complete control, which includes administration, works management, design, and general organisation. Must be a gentleman of undoubted ability and initiative, and must have held a similar position.—Write, BOX 7404, care of A. J. WILSON & Co., Ltd., 154, Clerkenwell Road, London, E.C. F 438

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Draughtsman Wanted, Young man with experience of commercial motor work. Applicants must be ineligible for military service. No one at present on Government work will be engaged.—Apply, nearest LABOUR EXCHANGE, mentioning this Journal and F 452.

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THE TENSILE STRENGTH OF ASBESTOS ROPE WHEN EXPOSED TO FIRE.

By J. Bobaricoff and W. Mramornoff.

The fire-resisting qualities of asbestos have received many practical applications, and it has at various times been suggested that ropes of this material might prove serviceable as life-lines at fires. Indeed, F. Cirkel has given some figures showing the safe load on asbestos ropes having a core of other material. He states that a rope of this kind ½ in. in diameter was good for 200 lb., the corresponding figures for ropes ¾ in. and 1 in. in diameter being 300 lb. and 500 lb. respectively.

Naturally, ropes with a metallic core are stronger than ropes consisting solely of asbestos, and the authors have accordingly considered that some results they have recently observed might be of interest. The tests were made in connection with the recent exhibition of fire appliances at Tomsk, Western Siberia.

The ropes tested were three in number, two being of asbestos and the third of hemp. The larger of the two asbestos ropes (No. 1) was 1 in. in diameter and was built up of $4\times4\times4\times3\times3=576$ primary yarns. No. 2 rope, also of asbestos throughout, had $3\times3\times3\times3\times3=243$ primary yarns; whilst No. 3, the hemp rope, consisted of $7\times3\times3=63$ yarns. None of the ropes had a core of other material. Rope No. 1 weighed 0.5 kg. per metre run; rope No. 2, 0.3 kg. per metre run; whilst the weight of rope No. 3 was 0.2 kg. per metre. The pitch of the strands was 10 cm. in the case of rope No. 1, and 6 cm. in that of No. 2. The asbestos used (chrisotil) came from the Urals and had the following chemical analysis:—

SiO_2	48.88
$Al_2O_3 + Mn_2O_3$	2.05
Fe_2O_3	2.70
CaO	0.50
MgO	46.00
Total ...	100.13

The hygroscopic water ranged from 1.1 to 1.2 per cent. at 18 deg. Cent. with the air at 50 per cent. humidity. The organic matter (linen fibres and the like) was small, but the loss of weight on driving off the water of crystallisation was about 6 to 7 per cent.

The first series of tests were made with the ropes in condition as received and with the following results:—

	Breaking Load. Kilos.	Average Elongation. Per Cent.
Rope No. 1.—Specimen *a* ...	1100	—
„ *b* ...	1090	—
„ *c* ...	980	—
Average ...	1060	23.3
Rope No. 2.—Specimen *a* ...	350	—
„ *b* ...	345	—
„ *c* ...	335	—
Average ...	345	26.0
Rope No. 3.—Specimen *a* ...	820	—
„ *b* ...	860	—
Average ...	840	28.0

As the ropes, if used in fires, would be liable to be wetted, it was considered of interest to test the asbestos ropes after three days' immersion in water. After this period of immersion the ropes had ceased to gain weight by absorption. The results were as follow:—

	Breaking Load. Kilos.	Percentage Loss of Strength.
Rope No. 1	930	12.3
„ 2	330	4.4

The effect of the water was thus more marked with rope No. 1, which had less twist.

To economise material the remaining test was made with strands unwound from the ropes in place of using the rope complete. As is known, the strength of a rope is in general less than the sum of the strengths of its component strands. These additional tests bore more especially on the effect on the strength of the rope of heating it to different temperatures in an Hereaus electric furnace. The maximum temperatures reached were maintained for three hours in every case. Of the three main strands provided by a length of rope one was tested in its natural condition. The other two were heated for three hours to the temperatures noted below and then cooled down to the normal temperature. One was then tested as it stood, whilst the other was first saturated with water. The results are shown in the annexed tables:—

Table I.—*Strength of the Strands of Rope No. 1 in Various Conditions.*

Temperature of Furnace.	Condition of Test.	Breaking Load.	Percentage Loss of Strength. Absolute.	Compared with Unheated Strand.	Compared with merely Cooled Strand.
Deg. C.		Kg.	Kg.	Per cent.	Per cent.
—	Unheated	85.0	—	—	—
220	Cooled after heating..	87.5	−2.5	−2.9	—
220	Wetted after cooling..	64.0	21.0	24.7	27.0
—	Unheated	80.0	—	—	—
270	Cooled after heating..	72.8	7.2	9.0	—
270	Wetted after cooling..	53.5	26.5	33.1	26.5
—	Unheated	73.0	—	—	—
360	Cooled after heating..	54.8	18.2	24.8	—
360	Wetted after cooling..	42.5	30.5	41.8	22.5
—	Unheated	85.0	—	—	—
400	Cooled after heating..	66.3	18.7	22.0	—
—	Unheated	72.8	—	—	—
500	Cooled after heating..	54.0	18.8	25.8	—

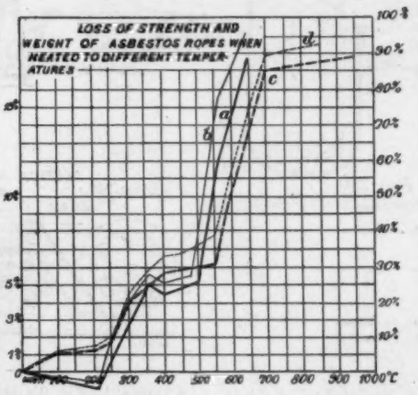


Table II.—*Strength of Strands of Rope No. 2 under Various Conditions.*

Temperature of Furnace.	Condition of Test.	Breaking Load.	Percentage Loss of Strength. Absolute.	Compared with Unheated Strand.	Compared with merely Cooled Strand.
Deg. C.		Kg.	Kg.	Per cent.	Per cent.
—	Unheated	60.7	—	—	—
225	Cooled after heating..	61.7	1.0	1.6	—
225	Wetted after cooling..	44.8	15.9	26.2	27.4
—	Unheated	53.0	—	—	—
275	Cooled after heating..	45.0	8.0	15.1	—
275	Wetted after cooling..	37.0	16.0	30.0	17.8
—	Unheated	56.0	—	—	—
360	Cooled after heating..	40.3	15.7	28.0	—
360	Wetted after cooling..	31.7	24.3	43.4	21.43
—	Unheated	59.0	—	—	—
400	Cooled after heating..	44.0	15.0	25.4	—
—	Unheated	55.0	—	—	—
480	Cooled after heating..	40.0	15.0	27.3	—
480	Wetted after cooling..	32.8	23.0	41.8	20.0
—	Unheated	57.0	—	—	—
500	Cooled after heating..	36.0	21.0	36.9	—
500	Wetted after cooling..	32.0	25.0	43.8	11.1
—	Unheated	59.0	—	—	—
560	Cooled after heating..	13.7	45.3	78.8	—
—	Unheated	59.0	—	—	—
650	Cooled after heating..	1.8	57.2	97.0	—

The results above tabulated show clearly that the strength diminishes very rapidly as the temperature to which it is heated is increased. Saturating the rope with water also greatly diminishes its resistance.

In the foregoing experiments the temperature was raised to the limits stated at the rate of 10 deg. Cent. per minute, and the specimens were exposed for three hours to the limiting temperature. A second series of experiments were afterwards made, in which the specimens were immediately cooled down again so soon as the limit temperature was reached. The results showed that the loss of strength was increased by prolonged heating. The observations made are recorded below:—

Table III.—*Rope No. 1.*

Temperature.	Breaking Load.	Loss of Strength.		Remarks.
Deg. Cent.	Kg.	Kg.	Per cent.	
280	88.25	−3.25	−3.8	The strength of the unheated strand was 85 kg.
450	64.30	20.7	24.5	
600	53.0	32.0	37.6	
710	24.75	60.25	70.9	
750	9.0	76.00	89.4	

Table IV.—*Rope No. 2.*

Temperature.	Breaking Load.	Loss of Strength.		Remarks.
Deg. Cent.	Kg.	Kg.	Per cent.	
280	59.0	—	—	The strength of the unheated strand was 59 kg.
450	42.3	16.7	28.3	
600	23.3	35.7	60.5	
710	7.7	51.3	87.5	
750	0.0	59.0	100.0	

With a view to obtaining some clue to the reason for this loss of strength on heating it was decided to determine the loss of weight when the asbestos was heated for three hours in the electric furnace and allowed to cool in a desiccator. The results were as follow:—

Table V.—*Loss of Weight on Heating for Three Hours.*

Temperature.	Rope.	Loss.	Rope.	Loss.
Deg. Cent.		Per Cent.		Per Cent.
100	No. 1	1.12	No. 2	1.19
200	„	1.31	„	1.51
250	„	1.79	„	1.92
300	„	3.87	„	4.51
350	„	4.77	„	5.68
400	„	5.57	„	6.63
450	„	5.72	„	6.83
550	„	6.27	„	7.73
600	„	10.25	„	11.52
660	„	14.23	„	15.93
700	„	17.01	„	17.89
750	„	17.15	„	18.15
850	„	17.49	„	18.54
950	„	17.54	„	—

The figures tabulated in Tables I, II, and V have also been plotted on the diagram annexed. In this diagram the full lines *a* and *b* show the loss of strength, and the dotted ones the loss of weight. The thick lines refer to rope No. 1, and the thin to rope No. 2. It will be seen that loss of strength and loss of weight for the most part run together, but where the maximum temperature does not exceed 200 deg. this rule fails. Up to this temperature, however, the effect of the heating is merely to dry the rope. The rapid loss in resistance occurs, it will be seen, at a somewhat lower temperature than the corresponding rapid loss in weight. This is apparently due to the heat destroying the coherence of the constituents somewhat sooner than it is able to expel the products of the decomposition.

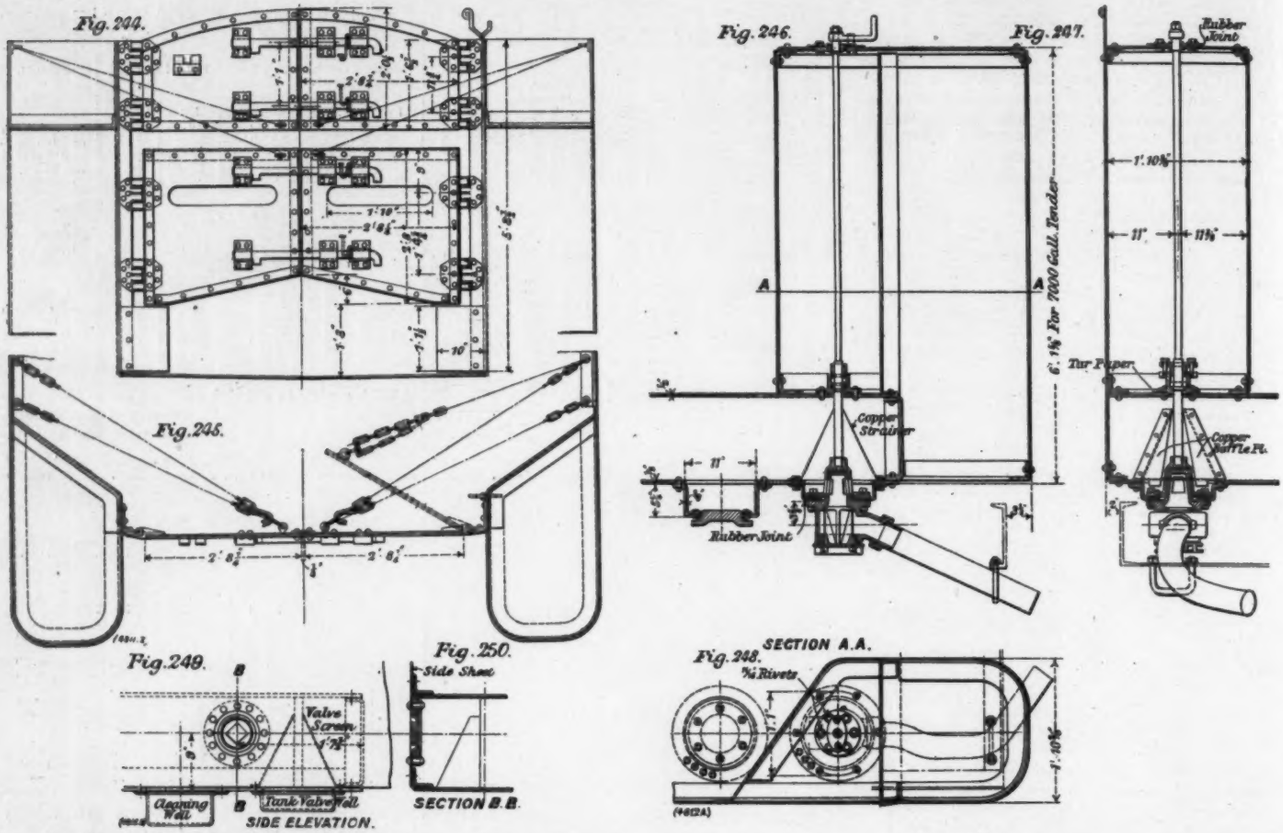
The large loss both in strength and weight between 200 deg. and 350 deg. Cent. is due to the burning out of the organic matter. The resulting characteristic smell was noticeable during this period. The loss of the combined water between 500 deg. Cent. and 700 deg. Cent. greatly reduces the resistance, which falls to less than 10 per cent. of its initial value.

Since a rope might be heated when in use at a fire, some further tests were made. Three strands were heated in the furnace, one being loaded. The temperature was raised until the strand broke. The other two strands were then removed and cooled, one of the two being subsequently saturated with water. The results obtained were as follows, each figure given being the average of four tests:—

In the first series the strand was loaded with a weight of 30 kg. and broke when the temperature reached 650 deg. Cent. The same strand unheated showed a resistance of 70.5 kg., heated and cooled 39 kg., wetted after heating 31.0 kg. In a second set of tests the load carried was 35 kg., and failure occurred at a temperature of 665 deg. Cent. In this case the unheated strand broke with 80 kg., heated and cooled with 26 kg., and wetted after cooling with 37 kg. In a third test the load carried

DETAILS OF 9,000-GALLON TENDER; PENNSYLVANIA RAILROAD.

MR. J. T. WALLIS, GENERAL SUPERINTENDENT OF MOTIVE POWER.



was 35 kg., and the strand broke at 540 deg. Cent. Unheated, its strength was 84.5 kg., the corresponding figure when heated and cooled being 47 kg., and when wetted after cooling 32 kg. In a fourth test a strand broke with 35 kg. at 690 deg. Cent., its strength unheated being 152 kg. All the above tests were made with rope No. 1.

In addition some experiments were made on the effect of repeated heatings followed by cooling in water. A number of specimens were thus raised three times to 400 deg. Cent., cooled twice and then broken. With rope No. 1 the average strength was reduced by this treatment from 80 kg. to 66 kg., the corresponding figures for rope No. 2 being 54 kg. and 53 kg. It would appear, therefore, that repetitions of the heating process have relatively little effect on the strength.

For purposes of comparison some tests were also made on the effect of temperature on the strength of the hemp rope No. 3, with the following results:—

	Breaking Load. Kilos.	Loss per Cent.
Temperature 140 deg. Cent.	110	15
„ 210 deg. Cent.	29.6	81.5

The tests give reason for concluding that asbestos ropes such as Nos. 1 and 2 cannot be considered as suitable for use as life-lines at fires, although they do have a little greater endurance than hemp ropes, as they retain 70 per cent. of their strength at temperatures of 250 to 500 deg. Cent. The authors are not aware whether steel-cored asbestos ropes are actually in use. No doubt such ropes would be stronger, but the asbestos would then serve merely as a heat-insulator. For this, however, it is not very well adapted, as it becomes very brittle at a temperature of 600 deg. Cent. In conclusion they may add that the whole of the above research was carried out in the mechanical laboratory of the Tomsk Institute of Technology.

HIGH-POWERED LOCOMOTIVES FOR THE PENNSYLVANIA RAILROAD.

(*Concluded from page* 353.)

The tank of the tender we are describing is shown by Figs. 239 to 243, on Plate XXXV, and from the views there given the details of the construction will be readily understood. It is capable of containing 9,000 U.S. gallons of water (about 7,200 English gallons) and there is nothing particularly new in its general design. At the front end the tank is fitted with the coal gates shown in detail by Figs. 244 and 245, on the present page. Several designs of coal gates have been tried on the Pennsylvania Railroad, but the pattern now illustrated has been found very satisfactory, and is now the standard type. As will be seen, the gates are made in four sections, each provided with a chain which enables it to be held in any desired position.

The tank valves, with strainers, deflector plates and cleaning-out hole, are shown in Figs. 246 to 248, on the present page, while Figs. 249 and 250 show an inspection hole which enables the front part of the tank to be examined to ascertain if all parts are clean and in good order.

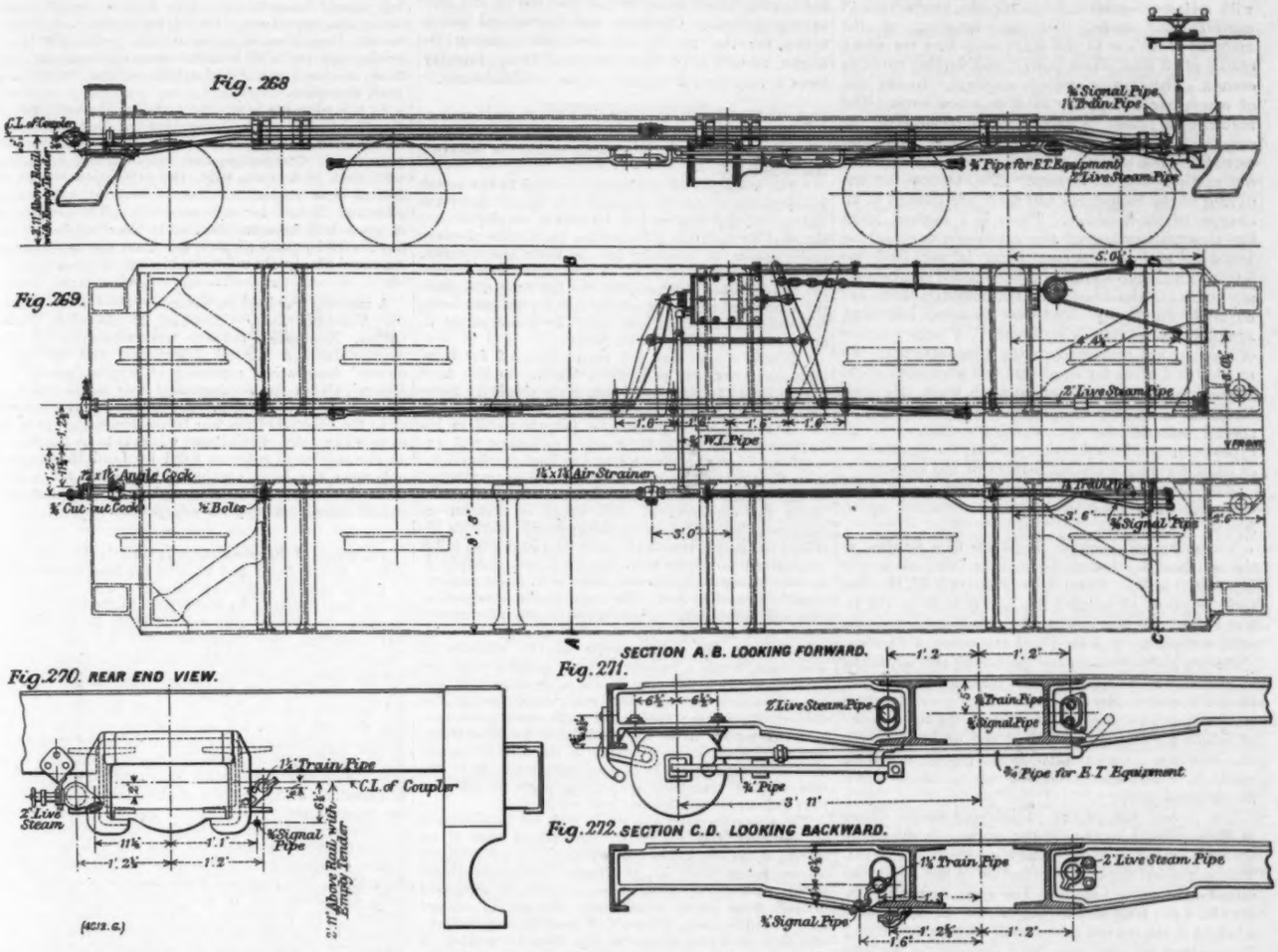
All tenders of the class under notice are fitted with water scoops operated by compressed air. The scoop itself is exactly like the hand-operated scoop used in the earlier equipment, which had for many years been the standard pattern on the Pennsylvania Railroad. Some trouble was, however, experienced owing to the difficulty of raising and lowering the hand-operated scoop at high speeds, and it was therefore thought best to apply air cylinders to do the work. The arrangement and details of the gear adopted are shown in Figs. 251 to 267, on Plate XXXVI.

From Figs. 251 to 253 it will be seen that the lower movable part of the scoop is coupled by a link to a lever mounted on a short shaft, which extends laterally to the side of the tender frame and carries near its outer end a short arm, the upper end of which is coupled by a rod to the piston of an air cylinder fixed to the tender frame, as seen in Fig. 253. Sections of the air cylinder are given in Figs. 254 and 255, from which it will be seen that the piston is provided with a trunk which works in an extension of the cylinder formed by one of the cylinder covers. The cylinder is 6 in. and the trunk 3¾ in. in diameter, and the air acts on the full area of the piston when raising the scoop out of the water, and on the annular area (representing the difference between the areas of the 6-in. and 3¾-in. circles) when the scoop is being depressed. The arrangement of the air supply valve is such that the air pressure acts on the full area of the piston at all times, thus eliminating the possibility of the scoop dipper being jarred down so as to interfere with the rail. To adjust the mouth of the scoop so that it dips to the right extent into the water trough the device shown in Fig. 251*a* is provided, the sleeve nut A being turned up or down, as the case may require, to such a position that on the dipper being pulled down its lip stands 2 in. below the rail level when the surface B of the sleeve nut bears upon the yoke. There are two of these adjusting nuts, and their positions with regard to the other parts is shown clearly in Figs. 251 and 252. Raising or lowering the sleeve nuts by ¼ in. lowers or raises the lip of the scoop by 1½ in.

The air for operating the dipper is taken from the train line of brake pipes through a check valve to an auxiliary air reservoir mounted near the air cylinder, as shown in the plan Fig. 253, this reservoir and the air cylinder being connected by pipes to the operating valve, which is fixed at the front end of the tender on the side of the tool closet outside the coal gate, as seen in Figs. 251 to 253. The operating valve is shown in full detail by Figs. 256 to 266, which will not require explanation. It will be seen from Figs. 256*a* and 257*a* that the handle by which the valve is operated is provided with a locking device,

DETAILS OF 9,000-GALLON TENDER; PENNSYLVANIA RAILROAD.

MR. J. T. WALLIS, GENERAL SUPERINTENDENT OF MOTIVE POWER.



and is further protected by a guard plate to prevent it from being moved accidentally. It will also be noted that the design of the valve is such that all piping is connected to its base, and the valve and valve seat may be taken down for grinding without interfering with the piping.

The tender is fitted with the regular design of air brake adopted on the Pennsylvania Railroad, as shown in Figs. 268 to 272, on the present page, the brake cylinders being 12 in. in diameter. The views named also show the positions of the train signal pipe and of the 2-in. live steam pipe for supplying steam for heating purposes.

The "K 4 S" and "L 1 S" classes of locomotives, of which we have been giving an account, have been subjected to exhaustive tests in the test department of the Pennsylvania Railroad, and the results obtained are of great interest and scientific value. We propose on a future occasion to deal with these experiments, but for the present we can only give some chief facts. In the case of the "K 4 S" type the indicated horse-power developed ranged from 709.7 to 3,183.9, the maximum horse-power being obtained at a speed of 47.3 m.p.h. with a cut-off at 65 per cent. of the stroke. Under these conditions steam was admitted to the cylinders at the rate of 65,319 lb. per hour, and the heat units per indicated horse-power per hour amounted to 22,334 British thermal units. The most economical results as regards coal consumption were obtained when working with a cut-off at 15 per cent. and the engine running at 280 r.p.m., corresponding to a speed of 66.22 m.p.h., the consumption then being 1.52 lb. per indicated horse-power. With a cut-off at 25 per cent. the most economical result was 1.80 lb. per indicated horse-power per hour, the engine running at 240 r.p.m., corresponding to 56.76 m.p.h. The rates of coal consumption during the trials varied from 21.6 to 170.56 lb. per square foot of grate per hour, and the evaporation from 3.73 lb. to 17.97 lb. per square foot of heating surface.

In the case of the "L 1 S" class the indicated horse-powers developed during the tests ranged from 356, with a 20 per cent. cut-off and a speed of 7.2 m.p.h., to 2,837.2 i.h.p., with a cut-off at 60 per cent. and a speed of 31 m.p.h. The most economical horse-power was about 1,500, when the coal consumption was 2.5 lb. per indicated horse-power per hour. It will be remembered that the boilers of the two classes are identical, but the tests of the "L 1 S" class were made at lower speeds, the maximum being 31 m.p.h., corresponding to 170 r.p.m. Both classes of engine are doing excellent work and giving high efficiency, and in concluding our present account of them we desire to tender to Mr. J. T. Wallis, the general superintendent of motive power to the Pennsylvania Railroad, our thanks for the valuable information he has freely placed at our disposal.

THE TURIN ENGINEERING WORKS OF THE FIAT SAN GIORGIO COMPANY.

RECENTLY we published in ENGINEERING complete drawings of the Fiat heavy oil internal combustion engines for the submarine depôt-ship Ceara for the Brazilian Navy, the most powerful internal combustion engines so far built and working on board ship. The Fiat San Giorgio Company have made great advances in the manufacture of this type of engine, alike for land and marine purposes, and the illustrations which we publish on Plates XXXVII and XXXVIII of the engineering works of the company, situated at Turin, will be studied with interest, as they disclose interesting features in detail in workshop practice.

The works illustrated have been laid out especially for the manufacture of the engines referred to, and the equipment is such that, with the exception of large forgings and heavy castings, all the units for the engines are prepared and machined within the factory. A large part of the work done, especially since the beginning of the war, is necessarily for submersibles built in the firm's shipbuilding yard at Spezia, and also at other dockyards, not only in Italy but in other countries. In addition, the firm manufacture compressors, torpedo tubes, &c. Consequently much of the work is at the present time of a confidential character, so that we are not able to describe the processes of manufacture as fully as we could wish.

The works occupy a total area of 31,150 sq. m. (34,015 sq. ft.), of which 19,800 sq. m. (21,313 sq. ft.) are roofed in. Normally about 2,000 men are employed, but at present this number is greatly exceeded. There are two main blocks of buildings, known as the northern and southern sections. The main thoroughfare passes between them, but direct communication is ensured by the construction of two wide subways underneath the roadway. The southern section, which occupies an area of 13,650 sq. m. (15,177 sq. ft.), of which 11,100 sq. m. (11,948 sq. ft.) are roofed in, contains the older part of the establishment, and even here great advances have been made; the southern part includes also the foundry, the forging department and extensive

machine shops, of which latter we give views on Plate XXXVII.

The foundry consists of a large central shop for the casting of large parts, either in iron or gunmetal, with adjacent smaller shops for the production of medium-sized units. For the handling of the material there are in the main shop four travelling cranes of 15 tons lifting power, and various rotating cranes. The iron is melted in three cupolas, one of which has a capacity of 5 tons per hour. The material is raised to the charge platform of the cupolas by hydraulic elevators. For gunmetal work there is a battery of crucible furnaces sufficient for castings up to 3 tons. The stoves for the drying of the mouldings and cores are located in an annexe of the foundry. There is a modern plant for the preparation of the sands required in the foundry, and a separate room is provided for fettling and sand-blasting, with a special compressed air plant for the blast. In the foundry there are normally employed about 500 workers, but here, again, the total now is abnormal. A large number of women are employed in the preparation of the moulds and cores for small iron and gunmetal work. A considerable amount of research work has been undertaken by the company in the production of special material for the working cylinders in all types of internal combustion motors, the production of these forming a special feature of the foundry.

The forge produces medium and small-sized units for the engine, the hammers ranging up to 30 cwt.

The principal machine shops are now located in the southern section of the building. One of these is illustrated in Figs. 1 and 2, on Plate XXXVII. The total length is 86 m. (282 ft.), and it is 24 m. (78 ft. 9 in.) wide. It is served by two electric cranes, one with a capacity of 5 tons and the other of 7½ tons. This shop is designed for the machining and adjusting of pieces of medium size. The photographs suggest that a considerable amount of repeat or standard work is done, a noteworthy feature being the number of tables for the laying out of the units alongside the benches. Annexed to this shop is a testing room for the trials of engines up to about 1,000 brake horse-power.

The newer part of the engineering shops—those in the northern section of the works—is shown by the photographs in Figs. 3 and 4, on Plate XXXVIII. This is utilised for the construction of the larger internal combustion engines. The main bay is 165 m. (541 ft. 4 in.) long and 18 m. (59 ft. 6 in.) wide, with a height in the central part also of 18 m. (59 ft. 6 in.). It is served by one crane of a capacity of 40 tons and one of 10 tons. Amongst the important machines in use reference may be made to a planing machine to take in jobs 3.50 m. by 3.50 m. (11 ft. 6 in. by 11 ft. 6 in.), and having a stroke of 10 m. (32 ft. 10 in.); a lathe capable of dealing with jobs up to 5 m. (10 ft. 5 in.) in diameter, and a battery of radial drilling machines for the multiple boring of jobs up to a length of 10 m. (32 ft. 9.7 in.). On each side of the main bay are two floors, a ground floor and a gallery fitted with plant for the machining and erection of the lighter parts. Fig. 4, on Plate XXXVIII, is a view of one of these departments with the lighter machine tools. Specially noticeable are the convenient tables adjoining the various machines for the accommodation of the units as they are machined and the grids on which the workers stand. In one of these departments there is also situated the shop for the construction of the jigs and tools necessary for the various classes of work. This is a very extensive plant, as the Fiat San Giorgio build their engines absolutely to gauge, so as to ensure interchangeability and to facilitate the supply of spare parts.

Directly annexed to this main machine shop is a new testing room for the higher-powered engines, fitted with all the accessories for measurement, and with hydraulic dynamometers to absorb the power developed, up to 6,000 brake horse-power.

At the side of the main department, too, there are two sheds having a total length of 130 m. (426 ft. 6 in.) and a width of 12 m. (39 ft. 4.4 in.), used for the manufacture and mounting of torpedo tubes and other submarine appliances, as well as for plate works. Annexed to this workshop there is a large department for autogenous welding, as this process is largely used in the production of plate work for the war apparatus in which the works have specialised.

There is ample railway siding accommodation, and an interesting feature is that wells are provided for storing large quantities of the heavy oils used in engine trials. Chemical and mechanical laboratories for the testing of materials entering the works, as well as of those produced in the foundry, form a very useful adjunct to the establishment.

INDUSTRIAL NOTES.

The Secretary of the War Office makes the following announcement:—

"The attention of employers is called to the recent amendments to the Regulation 41A, made under the Defence of the Realm Act, by which employers are required to maintain a list giving particulars of every male person of military age in their employment. Hitherto, the employer has been required to revise the list at least once a month, but the list must now show the names and particulars of the men for the time being employed, and corrections must be made so as to maintain the accuracy of the list.

"Where a man has not been employed for more than one week, the particulars relating to him need not be added to the posted list, if the employer keeps and produces for inspection when required a record of the names of all such persons (whether still in his employment or not), their ages, addresses and exemptions, if any. After a man has been employed for more than a week these particulars will be transferred to the posted list and removed therefrom when he leaves the employment. The effect is that on an authorised inspection an employer should show on his posted list particulars of all males who have been in his employment for more than one week and, if required, produce a record of men who have been in his employment for a week or less. The requirement as to posting lists and maintaining records of casual and intermittent labour does not apply (*a*) where an employer, in compliance with the requirements of the Ministry of Munitions, keeps a register of male persons employed by him, or (*b*) in the case of mines, to employers who have furnished lists of their male employees to the Colliery Recruiting Courts, as such employers have been exempted from the obligation by the Home Secretary with the concurrence of the Privy Council. Special arrangements have also been made as to the lists of port transport workers in ports at which a Port Labour Committee has been set up."

The announcement also deals with the employment of deserters and absentees, and states that if an employer has any doubt as to whether a man is properly continuing in civil life, he should report particulars to the nearest recruiting office in order to safeguard himself from legal proceedings. Recruiting officers can, on application and proof of identity, issue to men who have been placed by a Medical Board in a category which is not being called up for service and who consequently have been relegated to the Reserve, or to men who have been found by a Medical Board unfit for any form of military service, a certificate that they are not liable for military service until they are called up. Such a certificate is a protection during its currency to a man who rightfully holds it and to any employer who engages him.

In a series of articles dealing with the manufacture of munitions in this country, Mr. Hall Caine makes the following statement:—

". . . It is a tremendous picture of war work such as the world has never before seen equalled in magnitude, and common justice requires that we should say that it is due in the first instance to the public spirit of the Captains of Industry (Generals of the King as surely as any on the Field, some leading their tens of thousands, others their twenties and thirties) who have submerged their private businesses in this malign but necessary business of the war as absolutely as the Temple of Philæ is submerged by the overwhelming waters of the Nile. Certain of them are said to be making fortunes. I know nothing about that. But I do know they are working for the Nation as they never worked for themselves, going up to their factories by the workmen's train in the morning, snatching a hasty lunch on the edges of their desks, and rarely returning home until the night shift has got under way at 7 or 8 o'clock. Nor can it be said that they are preparing a lucrative future for their private enterprises. The fine inscription to Chatham on the monument in the Guildhall says he 'made commerce flourish through war.' But a few years were sufficient to change the country's view of that kind of prosperity, and none of us know what is to happen to the munitions firms after the present war is over. . . ."

We read in *La Métallurgie* that the works in Paris and its vicinity are most active in the manufacture of munitions of all kinds. Two large new works close to Paris have recently started the complete manufacture of large calibre steel projectiles. These new works have been placed in a position to reap the benefit of the experience acquired by other works of longer standing and have thus been able to commence delivering almost immediately. Our French contemporary takes this opportunity for paying a deserved tribute to the large French metallurgical works, who have freely imparted to all manufacturers of the country the trade secrets which it had taken years of unremitting work to evolve.

In this connection we may state, on the authority of the *Rivista Marittima*, Rome, that the French Minister of Munitions employs at the present time 800,000 operatives. Comparing the output now prevailing with that of August, 1914, the proportion stands as 200 to 1 in regard to rifles, 70 to 1 for quick-firing guns and 25 to 1 for guns generally. The production of guns and ammunitions, adds the Italian review, has reached figures which a few years ago would have appeared absolutely unattainable.

A meeting was held on Saturday, the 4th inst., says the *Newcastle Daily Chronicle*, at the Coal Trade Offices, Newcastle, between representatives of the Northumberland Miners' Association and the Coalowners' Association, regarding an application by the Miners' Union for an increased war bonus to men earning minimum wages. A settlement was arrived at to the effect that the war bonus percentage payable to men in receipt of minimum wages is to be calculated on the minimum rates as fixed by Lord Mersey and not upon the basis earnings. There are not many men earning minimum wages, but such as are will benefit considerably by the adjustment.

The report of the proceedings at the private conference held in Birmingham last week of the Iron Associations of Great Britain has been issued. The conference, which was initiated by the South Staffordshire Ironmasters' Association, and was attended by close upon 100 members, was presided over by Sir George Hingley, Bart. The report states that matters affecting controlled establishments engaged the attention of the conference. A resolution in favour of net prices for bar iron was passed, and a national list of extras was adopted which has received the sanction of the Ministry of Munitions. Committees were appointed to deal with certain questions affecting hoop and strip iron. Standing committees were elected in relation to questions which are of a continuous character, and the interchange of information and recommendations are great achievements. The question of improvements in manufacture was discussed with the view of meeting future competition from sources outside the United Kingdom. The proposed trade bank was sympathetically discussed, and it was decided to support the project. The substitution scheme in relation to men engaged in iron and steel works showed that the ironmasters of Great Britain are thoroughly alive to the interests of the army and navy, both in the way of men and material. There was a long discussion on the nature of the replies to be sent to the Board of Trade Departmental Committee on the iron and steel industries, and it was decided that the questions are so important that a representative committee should be appointed to put forward the views of the trade. The results achieved, concludes the report, have led to an arrangement that a conference shall take place at certain intervals. The consolidation of the trade, representing many millions in capital, will most certainly have at all times a far-reaching influence on all those serious questions which affect it, especially at the present time.

The Birmingham conference here referred to was the outcome of one held last May in Manchester, at the instance of the Lancashire Association.

Speaking at a mass meeting of railwaymen at Aberavon last Sunday, Mr. J. H. Thomas, M.P., advocated State ownership of railways. With reference to the war, although it was hell let loose, the railwaymen would show themselves unworthy of their responsibility, said Mr. Thomas, if they did not do all that was humanly possible to prevent any industrial strike. The power of the working classes to strike, he added, must never be taken away, but power was only good and useful when it was used wisely. Once they prostituted that power they destroyed every influence they possessed and ruined their cause. He did not believe that when war was over all the women who had been brought into industry would suddenly be turned out of it. In regard to female labour he stated that "we had never admitted that women on railways were permanently employed and for that reason they were treated as casual labour and received a minimum rate. You have no right to quarrel with women merely because work is being performed by women, but what you have to prevent is women's labour being exploited in order to lower the standard

wages of male labour." Mr. Thomas added that a bonus for railway women was being arranged.

Recent reports in the daily press give the impression that the battleship Arizona, built in a Government Navy Yard, has been completed in record time and at a saving of millions of dollars to the Government. On what basis these claims are made we are at a loss to understand, says *International Marine Engineering*, New York. Although the statement has been made that the vessel was prevented from going into commission for a month on account of the lack of a crew, nevertheless, investigation has shown that as late as September 15 the ship was far from completion and the main turbines had not been run under a load.

As to the cost of construction of the ship, it is understood that in the peculiar method of book-keeping employed in the navy yards an overhead expense of only 32 per cent. is carried, whereas if the recommendations of the Board of the Secretary of the Navy were given effect to, the overhead expense would be about 75 per cent. of the direct labour. It is also understood that other items, such as leave with pay, which properly should be charged against the ship, are not included. The truth regarding this matter from the Navy Department would be gladly welcomed.

Dr. Everest deals as follows with the British Coal Tar Colour Industry in his recent report to the Huddersfield Technical College :—

"In June last you announced your decision to establish in Huddersfield a department that should devote itself to post-graduate and research work in matters connected with the coal tar colour industry—a department that should produce the highly trained technical chemists required by the coal tar colour industry, and become the national centre for specialised teaching and research in all chemical matters affecting that industry. The equipment of our temporary laboratories was sufficiently forward for work to commence in September. But though the best has been made of the space available, the interest shown in the matter has been so great that the laboratory and lecture-room space is already overcrowded, and no time should be lost in completing arrangements for the erection of the new buildings for the department. This is the more urgent in view of the fact that the carrying through of a great proportion of our work is utterly impossible in our present buildings. In the meantime arrangements are being made to give temporary accommodation for further workers in the department.

"Not only is teaching work proceeding but important research work also is in progress. The manner in which the various firms connected with the coal tar colour industry, both in and outside Huddersfield, have interested themselves in the undertaking and given very valuable assistance is exceedingly encouraging, and your decision to appoint as head of the department one who is not in any way tied by appointment to any particular firm has in no small degree been responsible for this. This decision will also greatly assist in attaining to your original aim—the establishment in Huddersfield of a laboratory for research and post-graduate work that shall be the national centre to which all firms connected with the coal tar colour industry shall naturally come for assistance, and around which all matters connected with the coal tar colour chemistry shall centre. The provision of research scholarships tenable in the department has received much attention, and a fund for their endowment is already in being, which, however, needs to be greatly increased, so that a really comprehensive scheme may be put into operation."

The Durham miners' wages were advanced by 5 per cent. last Friday, this being the fourth advance in the course of the present year. The preceding advance was made in August, when the wages were raised to 102½ per cent. above the 1879 basis.

It is stated in *The Marine Journal*, New York, that whilst in the past decade the fisheries of the United States have been depleted, the fisheries of England have increased in value by 100 per cent. The fisheries form the great nursery of seamen for a maritime power to draw upon and one that is recognised by all seafaring people. So far as the United States merchant marine is concerned, the American fishermen have been shut out as a source of supply through the Seamen's Act, which provides that an able seaman must have three years' experience in the deck department of steamers before he is eligible to that title. This, adds our contemporary, is how labour union legislation throttles the American merchant marine.

Ship carpenters and joiners of Portland, Oregon, says the same American journal, who have been receiving 4.50 dols. for an eight-hour day, have notified their employers that after November 15 they will demand 5 dols. per day. Metal workers in the steel shipbuilding plants are also preparing to demand an increase of pay. Every time an increase of wages is granted the cost of living goes up, and every time the cost of living increases higher wages are demanded. Where this is all to end is a problem that must be solved sooner or later. In the meanwhile, the fact exists that labour and food are having a lively race for advancement; at the present time they are running neck and neck.

According to *The Times*, it is understood that the Government Reconstruction Committee are about to appoint a sub-committee to investigate after-war labour problems, with special reference to the project for securing an industrial truce during the reconstruction period. Mr. Whitley, Chairman of Committees of the House of Commons, will probably preside. The Labour Party are also giving their minds to this important question. A committee of the party is now examining it in its various aspects. The preliminary meeting between representatives of the Parliamentary Committee of the Trades Union Congress and the Employers' Parliamentary Committee will be held in London on Wednesday or Thursday next.

STARTING DIESEL ENGINES WITH LOW COMPRESSION.

To the Editor of Engineering.

Sir,—Referring to Professor Watkinson's paper, now under discussion in Engineering, I beg to bring to your notice that, some months ago, I brought out a similar idea in an engine of my design. I was making use of the fact that the temperature at the end of the compression is not dependent upon the absolute compression pressures, but upon the ratio of the final pressure after compression to that before compression commences. In a paper issued May 10, I demonstrated that air filling a vacuum up to outside pressure reaches a temperature which is in the same ratio to the original temperature as the specific heat under constant pressure to the specific heat at constant volume. In a second paper, on June 28, I demonstrated that the same ratio obtains for any final pressure under the original pressure of the air (or gas) filling the vacuum. Then, I was making use of this fact for starting a Diesel engine which was designed to work with a compression pressure never exceeding 200 lb. per square inch. A copy of the paper referred to is enclosed.

Yours truly,
J. Lecoche.

Victoria House, Oulton Broad, Lowestoft.
November 4, 1916.

To the Editor of Engineering.

Sir,—If I may again beg for a little space in your columns in reference to this interesting subject, there are still a few points that seem worth referring to.

As regards Professor Hopkinson, I think we are now in substantial agreement, except on the one outstanding fact which only actual test can decide.

I agree with the last paragraph in his second letter. It is a point he has a right to claim.

Mr. Walker's second letter correcting the formula given in his first is very interesting. The expression he derives is, I believe, quite new and, if my views are correct, can only be interpreted as involving a varying value of P. Thus considered, the expression, when correlated to the body of established fact—that is fact established by carefully controlled experiments—should find a useful place in the developed theory of the internal combustion engine. At present I have not sufficiently mastered its significance to offer any helpful suggestion.

Mr. Walker's note that my "explanation of the high efficiency of the Diesel engine is probably only partly true," and that the high expansion ratio is the important factor—may be accepted without question. I would merely remark that, as a matter of fact, at present I have no complete explanation to offer.

I am not satisfied with the published explanations at present accepted as sufficient. None of them appear to take into account the whole of the known facts.

For instance, if the transmission of heat through the cylinder walls follows the ordinary law of conduction :

$$Q = K A \frac{T_2 - T_1}{s} t,$$

and if there is no such protective effect of the high temperature lamina as I drew attention to in your columns, and no such return of heat to the expanding charge as the late Lieutenant Wilkins has proved to exist—then the heat loss due to the great ratio of surface to volume of gas in the Diesel engine ought to give us a much less efficient engine than we actually have.

If we accept the thin lamina effect—as is now generally done—how do we account for it ? Is it due to a change in the conductivity of iron with change of temperature ? Forbes' experiments would suggest that this is so; though it would appear that a still greater change in the specific heat of the metal must be assumed in order to account for the facts—the two changes together causing a relatively very large change in the *diffusivity* of the surface lamina—the actual factor in question.

As regards the loss of heat by radiation from gas to surface, and return of heat at lower temperature from surface to gas, a chief factor appears to me to be the increased proportion of carbon-dioxide in the gas when expanding. Even a small percentage of CO_2 would enormously increase the absorptive power of the gaseous mass.

In passing, it may be remarked that if much CO_2 were present when starting a Diesel engine on Professor Hopkinson's method a very substantial fall in temperature when wire-drawing the incoming gas would take place. Fortunately this trouble will not occur.

The relation of density, $\frac{V}{S}$, and temperature to the total external radiation of a gaseous mass has been, I believe, worked out in some detail by various physicists, but I do not think their results have as yet been logically applied to the theory of I.C. engines.

Finally, I would like to re-state my conviction that in most cases a Diesel engine works most efficiently as a heat engine when its diagram approximates most closely to that of an ordinary gas engine; that at present there seems no means of preventing—specially with varying load—the *occasional* production of absolutely enormous pressures, resulting in great straining and occasional breakage of the affected parts; and that the future lies with a type of engine less subject to such derangement, working at more moderate pressures, and not requiring such an expensive luxury as injection air at 800 lb. per square inch. For the present, however, the Diesel engine remains the most fascinating and, as I think, puzzling of all problems presented to the student.

I remain, Sir, yours faithfully,
W. A. Benton.

Benton's Patents, Limited, 5, Grosvenor-chambers, Broad-st., Birmingham. November 7, 1916.

THE ACCIDENT TO THE QUEBEC BRIDGE.

To the Editor of Engineering.

Sir,—Mr. Skinner's admirable narrative in your last issue of the methods adopted for hoisting the suspended span into its position on the bridge is in all probability quite comprehensive from the bridge builder's point of view, but there are others who are interested in this accident, myself among them, to whom a simple diagram of the hoisting apparatus, on the lines of the jack and pump diagram, with a less elaborate description, would have been far more helpful than all these intricate details of upper yokes and lower yokes, overlapping yokes, top flanges of the lower girders of the upper yokes and bottom flanges of the upper girders of lower yokes, lower girders of upper yokes and upper girders of lower yokes and yokes of yokes, &c., until one gets so mixed with yokes that it is no joke to get a comprehensive idea of the working of the arrangement.

Is it too late to ask you to let us have such a diagram ? While writing on this subject I cannot help mentioning that I find it somewhat difficult to understand why the safety of such an immense structure, weighing over 5,000 tons, should depend on four comparatively insignificant sets of castings, each the size of a mere point compared with the size of the structure they support. It may be clear to the bridge builder, and I quite appreciate that something in the nature of a universal joint is necessary here, but it does not satisfy the ordinary mind; something much more substantial seems to be wanted. And why should these bearings project to such an extent, allowing the corners of the suspended span to drop something like 3 ft. or more in the case of failure ?

I am glad to hear that the design of the rocker casting will probably be changed, and I trust for other than mere sentimental reasons.

I apologise for the length of this letter.

And remain,
Blackheath, November 7, 1916. "A. G."

War Material Regulations.—In pursuance of the powers conferred upon him by Regulation 30A of the Defence of the Realm (Consolidation) Regulations, 1914, the Minister of Munitions orders that the war material to which the Regulation applies shall include war material of the following classes and descriptions, that is to say: steel hexagons, steel rounds and squares (tested), steel scrap of the following classes when sold without guaranteed analyses: heavy steel melting scrap; steel turnings and borings.

Maximum Prices for Coke, Iron and Steel.—With reference to previous Orders made by the Minister of Munitions applying the Defence of the Realm Regulation 30A to war material consisting of certain classes and descriptions of metallurgical coke, pig iron and steel, and to the General Permit for dealing in such war material, the Minister of Munitions, as from the 1st day of November, 1916, withdraws such General Permit, and in substitution therefor, permits all persons until further notice : (*a*) To buy, sell or deal in; or (*b*) offer or invite an offer or propose to buy, sell or deal in; or (*c*) enter into negotiations for the sale or purchase of or other dealing in the war material referred to in the above-mentioned Orders. But this does not apply (1) to a sale or purchase under a special permit granted by the Minister of Munitions or (2) to a sale or purchase of material, other than high-speed tool steel, which is not a transaction or one of a series of transactions involving the sale or purchase of two tons or over or (3) to any sale by a manufacturer of finished steel rolled from steel purchased by him or (4) to a sale or purchase of material, the export of which has been duly sanctioned. Upon any such sale or purchase the seller and purchaser shall comply with any directions whether of general application or otherwise which may from time to time or at any time be given by the Minister of Munitions with regard to the use or disposal of the said war material. A full list of maximum prices for coke, iron, steel and other metals is issued with this notification, and copies can be had by applying to the Director of Steel Production, Ministry of Munitions of War, Whitehall, London, S.W.

MACHINE TOOLS FOR MUNITION MAKING.

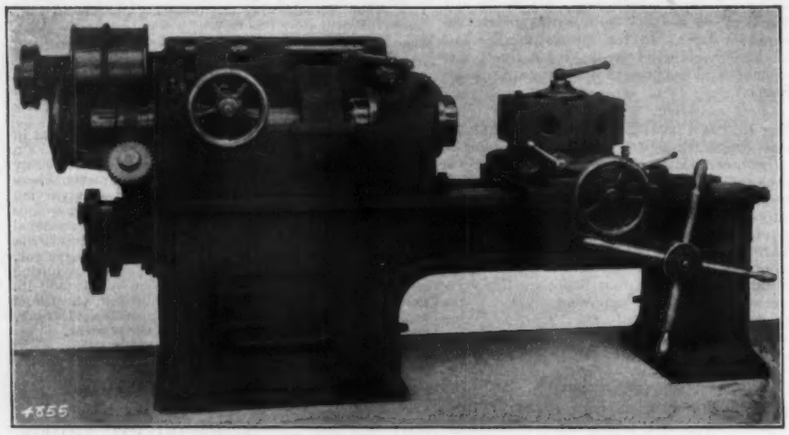


Fig. 1. 10¾-In. Centre Turret Boring Lathe for 4.5 In. and 5 In. Shells; Messrs. Pollock and McNab, Limited, Bredbury, near Stockport.

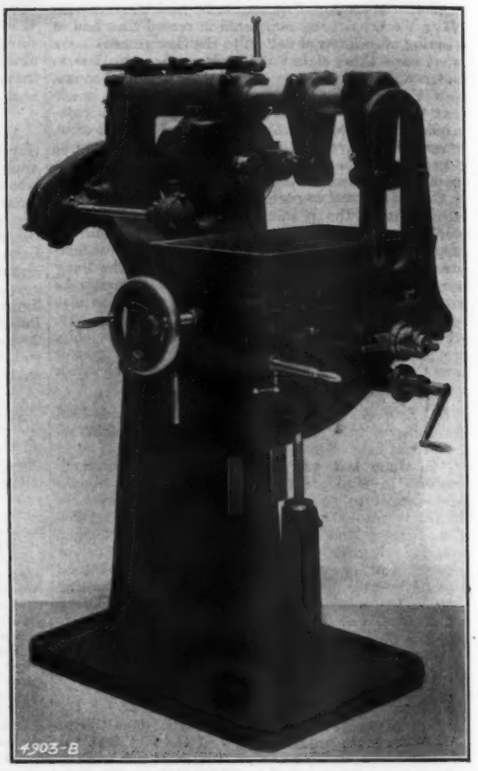


Fig. 2. Milling Machine for Small and Medium Components; Messrs. Archdale & Co., Ltd., Birmingham.

MACHINE TOOLS FOR MUNITION WORK.

10¾-In. Centres Turret Boring Lathe.

We illustrate in the view, Fig. 1, on the present page, a 10¾-in. centre turret boring lathe for 4.5 and 5 in. shells, manufactured by Messrs. Pollock and McNab, Limited, Bredbury, near Stockport. The holes in the turret are 3½ in. in diameter. The headstock is driven by friction pulleys controlled by the lever at the front; there are four speeds in either direction, which render the machine suitable for tapping. As no countershaft is required, all overhead preparations are dispensed with. The speed changes are of the sliding-gear type, controlled from the hand-wheel, also located in front of the headstock. The front bearing is of ample proportions, and the spindle is bored up to receive the collet for gripping the shell, thereby eliminating the overhang of the shell and the chucks. The spindle is bored throughout the entire length, and is fitted with a draw-in chuck. The chuck is opened and closed by means of the hand-wheel at the rear of the spindle. The feed motion is driven by spiral gears from the spindle and by worm-wheel and change wheels on to the guide screw down the centre of the bed. The guide screw is made so that the feed can be automatically disengaged when the turret has traversed the required length. The turret has six faces and is revolved by hand. Cramping bolts are provided for holding the tools rigidly in position. The turret has hand cross-traverse and automatic and hand traverse along the bed. The latter is of the box-end type under the geared headstock, and is fitted with a cupboard; it is supported at the outer end by a cabinet foot.

Manufacturing Milling Machine.

This machine, shown by Fig. 2 annexed, was specially designed for manufacturing operations on small and medium components where large quantities are required to be accurately and rapidly produced. It is largely used in rifle and machine-gun manufacture, Messrs. Archdale and Co., Limited, of Birmingham, having supplied large numbers to various gun factories since the war began. The illustration shows the machine arranged to be driven through single gear, fast and loose pulleys with belt shifter being provided. It can also be arranged to be driven direct by pulley without gearing. Where variations of speed are desired the machine can be driven by a three-speed cone pulley or by one cone pulley and single gear. When fitted with cone pulley drive a countershaft is supplied.

The spindle is hardened and accurately ground. It runs in hard phosphor-bronze bearings; the front bearing is conical and the back one parallel. The spindle is hollow and is provided with draw bolt for arbor.

The table has self-acting and automatic stop motion. The feed is positively driven, the feed screw and worm gears being of quick pitch with ball thrusts, thus giving ease and speed to hand movement and highest efficiency to the self-acting feed. The feed is changed by interchangeable gears, of which two are provided, giving two rates; others may be provided if desired. The longitudinal and vertical movements of the table have adjustable indexes.

A patent automatic feed engagement enables the work to be quickly moved by hand to the cutter, and at a predetermined distance from it the feed is automatically engaged, thus preventing damage to cutters and eliminating waste of time through idle feeding. This, when repetition work is being done, is of the greatest importance. The outbearings for the arbor are supported from a steel bar and braced to the knee bracket. The central support for the arbor shown in the illustration is supplied at an extra charge.

Special attention has been given to lubrication, oil wells and felt pads being provided for the spindle. The table has a specially deep tray, and a trough is cast around the base for lubricant.

The single-geared machine will take a cut 4 in. wide, 0.4 in. deep, at 1.9 in. per min. in mild steel under test conditions. The transverse traverse (self-acting) is 12 in., the longitudinal adjustment is 1 in., the vertical adjustment is 10½ in., and the approximate weight is 11 cwt.

THE SPERRY SEARCHLIGHT.

In our issue of September 1 we gave a general account of the Sperry searchlight, and we are now able to supplement that description by photographs and drawings. It will be remembered that the Sperry searchlight is distinguished by having a crater of very small diameter and intense brilliancy. This crater is not, of course, the mathematical point which the designer of optical apparatus assumes in making his calculations, but it approximates much more nearly to it than does the ordinary arc, with the result that the beam is very nearly parallel, and practically all its light falls upon the target instead of a portion being scattered over the surrounding objects. This, of itself, would give a better illumination, but in addition the luminosity of the crater is three or four times that of melting carbon, the aggregate result being that the brilliancy of the target is eleven times that resulting from an ordinary projector with the same current of 150 amperes.

In the Sperry arc the light is not radiated from melting carbon, but from a gas evolved from a chemical core or wick in the centre of the electrode. This core burns more readily than the jacket of carbon by which it is surrounded, and hence the crater is deep and well-defined. The resistance to combustion of the surrounding wall is increased by the cooling effect of a jacket or holder ventilated by a constant current of air, which keeps down its temperature and so maintains its form. The gas resulting from the volatilisation of the core, being at a very high temperature, would diffuse with immense rapidity were not special means provided to force it back into the crater and keep it there as long as possible. This is, probably, the most interesting feature of the whole design, for it is clear that upon this depends the success of the light, and that the problem is, on the face, one of immense difficulty. It is generally found that difficult conditions must be met—if met at all—by simple means, and this is exemplified in this case, for the gases are forced back into the crater by the non-luminous flame from the negative electrode which is directed into it. Of course they are not absolutely held there, but a strong pressure is exerted all over the mouth of the crater, and the leakage is reduced to a quantity that can be readily made up by the volatilisation of the core of the electrode. The negative carbon is of smaller diameter than the positive and stands at an angle to it, so that it does not intercept a great part of the radiation from the crater.

The lamp itself is shown in the annexed illustrations, and also the projector in which it is enclosed. Each electrode is carried by a hollow upright, which is very narrow so as not to obstruct the beam and is braced by two guy wires sideways. A current of air is forced up the interior of each upright by the fan shown as a disc in the centre of the box below the standards and driven by the small electric motor next to it on the right, which also serves to rotate the positive carbon to keep the crater exactly centred. This air current serves two purposes, each of which is important. First, it cools the electrode holder. This is a sleeve in which the carbon rotates and through which it is fed, and as this is close to the arc it would get exceedingly hot in spite of a quartz ring which forms its mouth. Upon the sleeve are a number of discs, like the flanges on the cylinders of motor-bicycles, and between these discs the air escapes, carrying away the heat, which they conduct outwards. Secondly, the exhaust air sweeps the gases out of the projector, and prevents their deposition on the mirror and the lens. This latter is a matter of considerable importance, for a very slight dimming of the mirror will reduce the light very seriously. The hood of the projector is also fitted with ventilating appliances to ensure a sharp draught through it at all times.

The positive electrode is 16 mm. in diameter and 110 cm. long, this great length being required on account of the high speed of burning of the cored carbon, which is about 18 cm. per hour with 150-ampere current. The carbon holder is kept in rotation by the vertical shaft shown at the back, which is driven from the electric motor by worm and spur gear, the current being conveyed to the carbon by silver brushes held up by springs. The carbon is held between feed rollers which revolve with it, and are partially rotated at each revolution by a star-wheel which comes in contact with the rod shown just behind the hollow standard carrying the carbon. This rod is capable of adjustment so that it causes the star-wheel to rotate through a smaller or greater angle at each contact.

THE SPERRY SEARCHLIGHT.

CONSTRUCTED BY THE SPERRY GYROSCOPE COMPANY, LIMITED, LONDON.

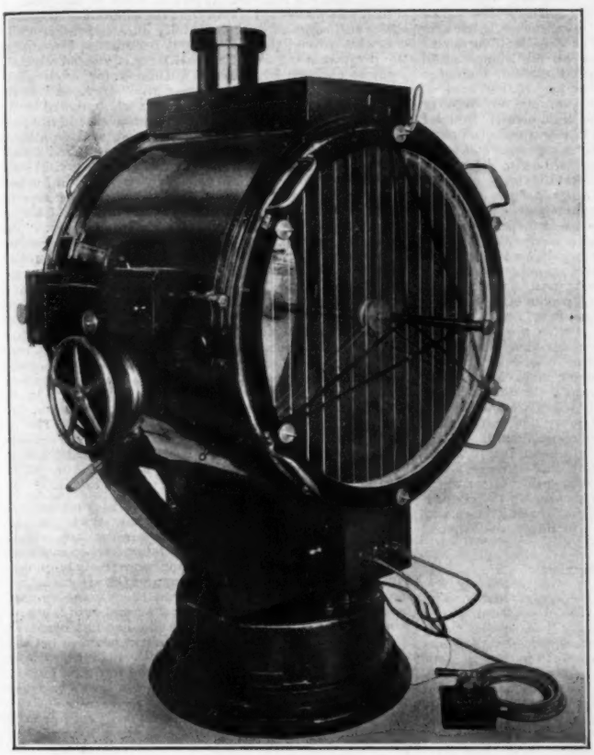


FIG. 1.

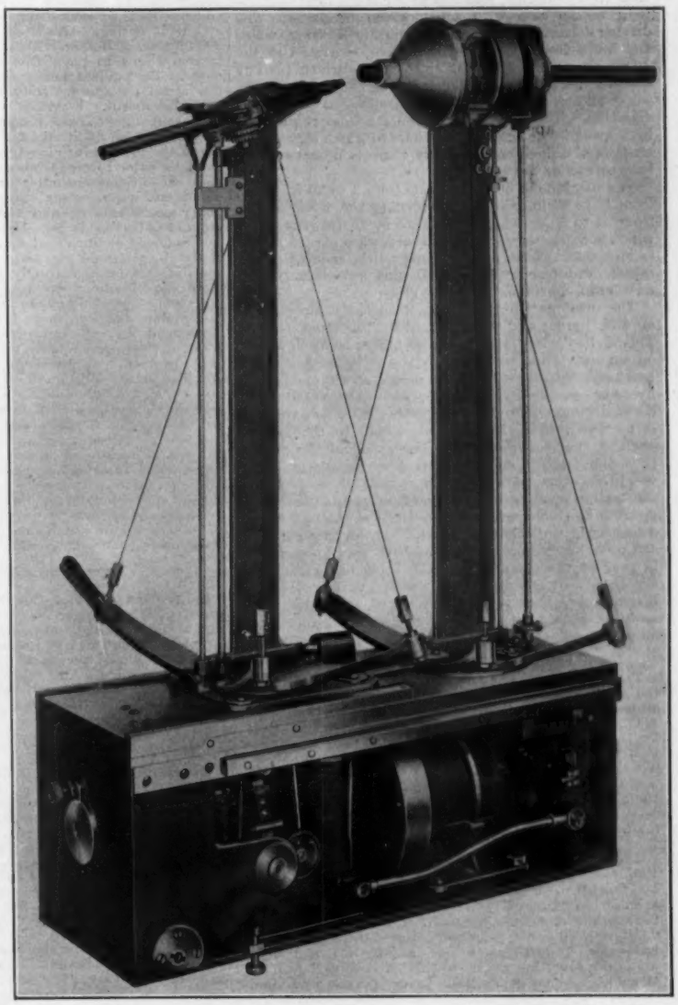
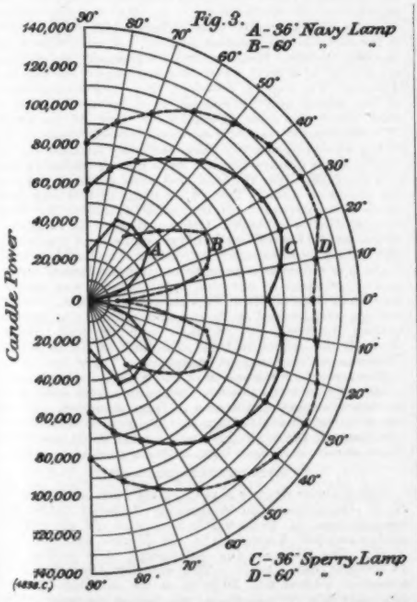


FIG. 2.



This adjustment may be made by hand by the operator, who watches the picture of the arc thrown by a lens on a ground glass screen in the usual way. The projector can, however, be fitted with distant control in the usual manner, and then the feed of the carbon has to be automatic. To this end there is fitted in the hood of the reflector a thermostat, consisting of two strips of metal fixed at one end and attached to multiplying levers at the other. These levers carry contacts at their ends, and these contacts are opened or shut when the arc moves from or to its correct position. There is a small focusing mirror which sends a reflected ray on to the thermostat when the arc has burned back out of the correct focus of the projector. The thermostat then expands and opens the contacts, whereupon a solenoid is de-energised and adjusts the vertical rod to give a quick feed. On the arc regaining its position the contacts close and the normal feed is re-established.

The negative carbon is not rotated, but is fed forwards by the fan motor, through the rod shown to front of the motor and the fan. The rate of feed is determined by a solenoid, which is inserted as a shunt in the arc, and comes into operation when the potential drop varies. An adjustable spring, opposed to the solenoid, fixes the voltage at which action occurs. The motion is transmitted to the feed rollers gripping the carbon through the vertical shaft shown behind the negative standard. The negative carbon is inclined at an angle of 14 deg. to the horizontal, and casts as little shadow on the mirror as possible. Its carriage can be turned about 10 deg. to the right to permit new negative carbons being inserted from the front, and when so turned the second vertical shaft is moved upwards a short distance by a cam and separates the feed rollers so as to permit a new carbon to be slipped into place.

The negative holder is mounted on a carriage which slides in a track on the top of the control box. When the current is off the carriage is moved up to the striking position by a strong spring. When the arc is struck the series solenoid moves the negative carriage and holder back to the proper running position.

The intrinsic brilliancy of the bright vapour in the positive crater is about 500 c.p. per square millimetre, and the distribution curve is more uniform than in the pure carbon arc. Fig. 3 shows the candle-power distribution curves for both 90 cm. and 150 cm. projectors of the standard carbon arc and the Sperry arc. The maximum candle-power of the former is 44,000 over a small angle, whilst the Sperry arc shows a maximum of 104,000 c.p. with a very wide angle of high intensity. In more recent tests 112,000 c.p. has been obtained for this size. The lamp is sold in this country by the Sperry Gyroscope Company, Limited, 15, Victoria-street, London.

PLANING MACHINE AND BORING AND TURNING MILL.

WE illustrate in Figs. 1 and 2 on page 460 a high-speed side-planing machine, and an 8-ft. boring and turning mill, both built by Messrs. George Richards and Co., Limited, Broadheath, near Manchester. The planing machine shown in Fig. 1 is driven by a steel chain and sprocket wheels. The drive is from the countershaft on to two pairs of fast and loose pulleys placed at the end of the machine parallel to the bed, the pulleys being driven by open and crossed belts for reversing and the belt gear being actuated in the usual manner by stops on the shipper rod.

A worm is fitted to the pulley shaft and engages with a worm wheel which drives the shaft carrying the driving sprocket wheels. Two chains are used to traverse the tool holder; they are connected to the the carriage by a swivel shackle to ensure both chains receiving an equal amount of pull. The worm runs in an oil bath, and the thrust is taken by roller bearings. The chains also run in an oil bath, and any slack in a chain is taken up by a stretcher having right and left-hand screws. The chains are accessible for this purpose by a removable cover at the bottom of the bed.

The return stroke of the carriage is made at the

rate of 150 ft. per minute; the cutting stroke is 40 ft. per minute, but the machine can be arranged for a cutting stroke up to 60 ft. per minute The driving chain forms a flexible rack; it has only hardened and rolling surfaces in contact, and this, together with the slow speed at which the chain runs, reduces wear to a minimum, and less power is required to drive than is the case with screw-driven machines. The driving-chain wheel being driven by a worm wheel and multi-threaded worm, less shock is caused at the point of reverse than in spur-gear-driven planing machines, owing to the surfaces of the teeth of the worm and wheel approaching each other in an angular direction. The only part of the machine running at high speed is the short pulley shaft to which the driving shaft is attached, consequently there is no reversal of long screws or heavy shafts.

The machine is made to plane from 3 to 30 ft. long; from 12 to 60 in. wide, or, by turning the work round, from 24 to 96 in. wide. The tools move over the work, which is fixed; large and small pieces are planed at the same speed. Pieces of any shape can be secured to the tables, and pieces weighing 10 tons have been planed on a 30-in. machine.

The machine shown in Fig. 2 on the same page is an 8-ft. boring and turning mill by the same makers. This is direct-driven, the electric motor being mounted on an extension bed cast to the driving headstock bracket. The drive from the motor to the machine is by spur gearing; this latter can be replaced by a silent driving chain when required. Intermediate gear is provided, so as to give two speeds to the driving shaft of the machine to any one speed of the motor, thus reducing the speed variation in the motor. The weighted lever shown on the left-hand side of the illustration operates the intermediate gear—one movement of this lever engages one wheel of the two whilst disengaging the other, and *vice versa*, and no accident can occur in this connection, as both wheels cannot be in gear at the same time. The table has a range of six speeds by gearing alone, this number of speeds being largely increased by the use of a variable speed motor giving a range in speed of 2 to 1. The elevating motion to the cross slide is given by the same motor.

The Royal Institution.—At a general meeting of the members of the Royal Institution, held last Monday afternoon (the 6th instant), the Duke of Northumberland, K.G., president, in the chair, Dr. H. E. Armstrong, Ph.D., F.R.S., was elected a manager in place of the late Professor S. P. Thompson. Resolutions of thanks were passed to Richard Pearce, Esq., for his donation of 100*l.*, and to John Y. Buchanan, Esq., for his donations of 100*l.* to the fund for the promotion of experimental research at low temperature and of 100*l.* to the general fund.

Carnegie Scholarship Memoirs.—We have received from the editor, Mr. G. C. Lloyd, Secretary of the Iron and Steel Institute, a copy of Volume VII of the Carnegie Scholarship Memoirs. These memoirs deal with "Iron-Carbon-Silicon Alloys," by J. H. Andrew (Manchester); "Deterioration of Refractory Materials, with Special Reference to Open-Hearth Practice," by H. B. Cronshaw (Cambridge); "Gases Occluded in Alloy-Steels," by J. W. Donaldson (Glasgow); "An Investigation of Liquid Contraction in Cast-Iron," by J. Hailstone (Smethwick); "The Oxygen Content of Iron and Steel, and its Effect on their Properties," by J. Allen Pickard (London); 'The Heat Balance of a Blast-Furnace Stove," by R. S. G. Knight (London); "Various Agents for the Deoxidation of Steel," by H. M. Boylston (Cambridge, U.S.A.); "An Apparatus for the Measurement of Electric Resistance and its Application to the Determination of the Critical Points of Iron and Steel," by P. Saldau (Petrograd); and "The Preservation of Iron and Steel by Means of Passivifying Factors," by T. G. Thompson (Seattle, U.S.A.). All these memoirs contain interesting information; the book covers 300 pages of carefully illustrated subject-matter and forms a valuable addition to the library of the Iron and Steel Institute.

The Institution of Electrical Engineers.—In his presidential address, delivered as chairman of the Western Local Section of the Institution of Electrical Engineers, Professor D. Robertson drew an analogy between the field of knowledge and a goldfield. The first-comers, he said, acquired the surface veins and nuggets with comparative ease and with the crudest equipment, but as these became exhausted their successors had to expend more and more preliminary labour without immediate return. This corresponded closely with the present state of affairs in practical applications of science, and the men required to open out the new ventures would not, he said, be forthcoming unless the prospect offered to them was comparable to that open to them in other professional careers. As matters stood, a clever lad, if he took up classics, had open to him every kind of well-paid Government post from judge to administrator; whereas, if he took up chemistry, he might, if fortunate, get the post of charge chemist in some Government factory at a salary less than that of the labourers he was called on to direct. The speaker suggested that a reform in these matters would be hastened if the scientific men and engineers who have repeatedly come to the rescue of the departments in emergencies insisted on an adequate return for their services, which in the past have often been given gratuitously.

NOTES FROM THE UNITED STATES.

Philadelphia, October 25.

Large domestic consumers are crowding into the market to secure material, in many cases up to mid-summer, 1917. Some European Governments are arranging for munition material for still more remote deliveries. In addition to this European buyers are endeavouring to secure supplies for delivery this winter and next spring. The French Government is seeking 20,000 tons of Bessemer bars. The British Government is also about to place this week an additional small order. The pig-iron market is much disturbed. Bessemer has again advanced. Italy is buying 12,000 tons of low phosphorus. Furnaces now running on foundry iron are turning to basic because of high prices. Holland has ordered an additional lot of 12,000 tons. Inquiries are in the market for pipe iron for a pipe-line 500 miles long, to extend from Oklahoma to St. Louis. This is in addition to the recent order for a 700 miles long pipe-line. Numerous inquiries for export are reported as being under consideration, and the quantities inquired for are said to be very large. Details are at present lacking. The oversold condition of American steel mills, in view of the development of enormous requirements for next year, is causing increasingly grave apprehensions, but these apprehensions are tempered with the anticipations of a sufficient expansion of producing capacity. Automobile builders have become very large buyers. Implement makers are proceeding with much caution. Wire products have been further advanced 2 dols. a ton. Despite high prices inquiries continue to pour in. The plate condition is very much unsettled. Prices this week will advance to 4¼ cents. A Seattle shipyard has closed a contract with the Carnegie people for 14,000 tons of plates and shapes. The entire iron and steel situation is becoming more uncertain. If the prospective additional capacity could be known it would afford some measure of relief, but the increase is an unknown factor. Domestic requirements will certainly assume very much larger dimensions during the coming year. Railroad traffic is overtaxing railroad facilities, and assurances cannot be had as to prompt shipments because of the shortage of rolling stock.

Light Brass Work Contracts Available.—The Ministry of Munitions is desirous of extending the output of casting and stamping fuze bodies and sockets, and casting and rolling brass rods for the components. Firms possessing suitable machinery and capable of undertaking such work are requested to communicate at once with the Central Clearing House for Engineering Resources, Ministry of Munitions, 8–9, Northumberland-street, Northumberland-avenue, London, W.C.

Determination of Nominal Horse-Power in Special Cases.—Under Section 92 of the Merchant Shipping Act, 1894, foreign-going steamships of 100 nominal horse-power or upwards are required to be provided with at least two certificated engineers. The following alteration is made in the formula to be used by surveyors for determining the nominal horse-power where there is doubt whether the N.H.P. is over or under 100. The present formula is—

$$\text{N.H.P.} = \frac{S}{30},$$

where S is the sum of the squares of the diameters in inches of all the cylinders. The formula to be used in such cases in future is—

$$\text{N.H.P.} = \frac{(3\,H + D^2\sqrt[3]{S})\sqrt[3]{P}}{700}$$

where

H = heating surface of main boilers in square feet, measured down to the level of the fire bars, but excluding the front tube plate.

D^2 = square of diameter of low-pressure cylinder, or sum of squares of diameters of cylinders in non-compound engines, measured in inches.

S = length of stroke of engines in inches.

P = pressure of main boilers in pounds per square inch.

Colombo.—The drainage of Colombo (Ceylon) has been undertaken by the Colonial Government at the request of the Municipal Council, the necessary funds being advanced on loan by the Ceylon Treasury. Further assistance is also being given by the contribution of a part of the expenditure as a free grant. The scheme which has been adopted provides for a complete system of sewers and rain-water drains throughout the city, and for the disposal of the sewage by bacterial treatment upon modern lines. At the close of 1915, 115 miles of sewers and rain-water drains had been laid and five pumping stations had been brought into regular operation. In spite of a reduction of expenditure necessitated by the war, progress has been maintained in increasing warehouse accommodation and other facilities at Colombo; six new warehouses and a covered roadway on the old coaling grounds immediately east of the passenger jetty have been completed by the Public Works Department, and have been handed over for use. A system of quay walls between the patent slip and block jetty, and of the quay walls of a canal leading to the harbour, have considerably advanced. A water service has been laid throughout the Customs premises, and arrangements have been made for supplying shipping, with meters on the south-west breakwater, thus relieving the congestion of the foreshore used for coaling and the discharge of cargoes.

NOTES FROM SOUTH YORKSHIRE.

Sheffield, Wednesday.

South Yorkshire Coal.—The position all round has undergone considerable tightening since the last report. The two principal factors are the congestion in the railway traffic to and from the collieries and the scarcity of trucks, and the reduced output of many of the pits. A return just presented shows that the amount of absenteeism is still so great as to be totally unsatisfactory, whilst it is also proved that the output per man is lower than the pre-war standard. The last item is viewed with the greatest concern by those in authority, for, even allowing for the fact that there are many "novices" in the pits in the place of experienced men who enlisted in the early days of the war, the output per man should not have fallen off so greatly. The remedy does not lie in making the men work overtime, for this is not permitted by the Eight Hours Act. All classes of fuel are affected in some degree or other. The market has a strong tone for best steam hards, which are wanted in large quantities for railways, munition works, and other industrial undertakings at home, and also for Allied Powers. The deliveries to works are sufficient for daily requirements. Italy and France continue to receive a steady weekly figure, but the export trade to neutrals is not in a very happy condition. This is the outcome of the shortage of freights, for there are many forced sales at ports following upon the non-arrival of expected ships. Gas-makers are taking the full output on contract account. The house coal position shows little change apart from the unusually heavy requirements of the London merchants. Quotations: Best branch hand-picked, 20*s.* 6*d.* to 21*s.* 6*d.*; Barnsley best Silkstone, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire best brights, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire house, 17*s.* to 18*s.*; best large nuts, 16*s.* 6*d.* to 17*s.* 6*d.*; small nuts, 15*s.* 6*d.* to 16*s.* 6*d.*; Yorkshire hards, 16*s.* 6*d.* to 17*s.* 6*d.*; Derbyshire hards, 16*s.* to 17*s.*; best slacks, 12*s.* to 13*s.*; seconds, 10*s.* 6*d.* to 11*s.* 6*d.*; smalls, 7*s.* 6*d.* to 8*s.* 6*d.* per ton at pit.

Iron and Steel.—The demand for steel for all national purposes continues to keep the whole trade busy in meeting requirements. Works extensions are almost continually taking place, and new labour, when available, is engaged. Women are now being more freely employed, but the greatest demand is for men of the strong labouring class. It was anticipated that the "combing-out" measures would reduce still more the number of labourers from the trade, but so far the result has not been very marked. This is the outcome of a compromise between the works and the military, whereby men who do not come up to the "A" standard in the military physical classification, *i.e.*, general service, are allowed to return to the munition works, where they are obviously of greater value to the country than on sedentary or other non-combatant military duties. This is a welcome concession to the works, which are all running at top speed. There are few features to record in the common iron market. Buying is on a small scale and, for the first time for many months, makers are reported to be offering consignments below the official maxima in order to induce purchasers to do business. In the foundry section matters are unusually quiet. Derbyshire forge quality is far away in the greatest request, but even here trade has been better. Hematites are unchanged, the demand remaining at a level which absorbs nearly the full production. For export, however, there is a strengthening of the prices, and East Coast varieties are 18*s.* dearer than the home sales quotation of 122*s.* 6*d.* on truck. The scrap metal market is devoid of interest, trade having fallen away appreciably since the busy summer period. The London County Council have placed contracts with five Sheffield firms for iron and steel castings required for tramway work. Two other firms in this city have received contracts from the same authority for large numbers of twist drills. Other orders of an important character are for colliery haulage engines and machinery, and rolling stock for army purposes. The hacksaw blade trade is in a flourishing condition, but the British output is not yet equal to our own requirements, and supplies have to be obtained from Canada and the U.S.A. Cutlery makers, with limited staffs and with difficulty in securing hafting material, are finding it a severe task to complete all the orders on hand, the bulk of which are for Government and export purposes. There are many indications of an expansion of the general overseas trade of the city, and the Cutlers' Company is still issuing the necessary export certificates in large numbers. Of the latest indents from foreign and Colonial customers the following are the most important: saws, tools, machetes, sheep shears, steel sash bars, springs, steel and cutlery.

The United States Navy.—Bids were opened at the Navy Department on Wednesday, October 25, for the construction of four battleships and 20 destroyers, authorised last August, says *The Marine Journal*, New York. The bids on the battleships were within the 11,500,000 dols. limit. The shortest time for construction quoted was 39 months for one ship, and all four will take 45 months at the lowest estimate. The bids for the four battleships—Colorado, Maryland, Washington and West Virginia—ranged from 10,000,000 dols. to 11,425,000 dols. The Fore River Shipbuilding Company will get two and the Newport News Shipbuilding and Dry Dock Company the other two. The Department received 24 offers for the construction of the 20 destroyers. The limit of cost was 1,200,000 dols. each. Bids ranged from 1,150,000 dols. to 1,195,000 dols. each, and the time of delivery from 22 to 28 months. The Bath Iron Works, the Union Iron Works, the Fore River Shipbuilding Company and the Cramp Company will doubtless obtain these contracts. On the 1st inst. the Department was to open the bids for four 25-knot scout-cruisers and 20 submarines.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Glasgow Pig-Iron Market.—In the pig-iron warrant market matters remain at a complete standstill, while the depletion of the stocks in public store steadily continues. There is, consequently, nothing to note in this connection.

Scotch Steel Trade.—It would be almost impossible to imagine conditions of greater activity than those prevailing in the steel-making industry throughout Scotland, and perhaps more particularly in the West, the entire available plant being fully employed at the highest pressure fulfilling orders for the British and the Allied Governments. Shell bars and billets are being turned out in extraordinary quantity for the Ministry of Munitions, while plates and sectional material required by the Admiralty are likewise much in demand—the former, however, being the most important at the moment; work of the latter class has quite often to be left aside for a time. Enquiries for mercantile business cannot meantime be entertained. Prices are much on the level of last week—ship plates, 14*l.* to 14*l.* 5*s.* or so per ton; boiler plates, 15*l.* 10*s.* off and on; and angles, 14*l.* 7*s.* 6*d.* per ton.

Malleable Iron Trade.—The pressure experienced now for some considerable time in the malleable iron trade shows no sign of slacking off, Government being, practically, the exclusive consumer of the whole output in the steel departments. As no licence for shipment abroad is yet required for the product of the iron departments, quite a good measure of export trade is being put through. "Crown" bars for export are now quoted 14*l.* 12*s.* 6*d.* per ton.

Scotch Pig-Iron Trade.—With the abnormal demand for pig-iron of all grades it is feared that the available supply may fall short before very long, much as such a state of affairs would be deplored. The difficulty, however, of obtaining the necessary amount of raw material still constitutes a condition of affairs not easily surmounted by the makers. The number of furnaces now being employed in the production of hematite—still greatly in request—is in large measure responsible for the threatened scarcity of foundry sorts, No. 1 in particular being an elusive commodity. Every possible ton is meantime being reserved entirely for the use of Government. Home prices, of course, are still fixed, and export keeps steady, although little business is being done except on war account.

Shipbuilding in October.—Although the tonnage of new mercantile shipping is still much below that of normal times, the total in October is considerably above the average of any other month during the year, and shows that, under the circumstances, cargo-carrying shipbuilding has been satisfactory. On the Clyde seven vessels of a net tonnage of 17,042 tons were launched, bringing up the figures since January to a total of 41 vessels, with a gross tonnage of 118,468 tons. One vessel—a screw tug of 214 tons—built by Messrs. John Cran and Co., Leith, for a Liverpool firm, was launched on the Forth; and a steam trawler, built by Messrs. A. Hall and Co., Aberdeen, for a Grimsby owner, was launched from Aberdeen. In addition to the very important work being executed on the Clyde for purely naval purposes, there is also a fair amount of work of a semi-mercantile character being put through on Government account. Although there is not much appearance of any improvement, yet the submarine warfare on mercantile shipping must, in the very immediate future, create an exceptional demand for new vessels. Some little dilution of labour in the shipbuilding yards has already taken place—more must follow soon. The following table gives the figures for October on the four principal rivers in Scotland :—

Clyde.		Forth.		Tay.		Dee.	
Vessels.	Tons.	Vessels.	Tons.	Vessels.	Tons.	Vessels.	Tons.
7	17,042	1	214	—	—	1	200

During the month no new orders have been placed.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Business in Cleveland pig-iron is on a moderate scale. A few sales are still being made to Scotland, but this month's requirements of consumers North of the Tweed have now been fairly well met so far as sales are concerned. Home consumers' immediate needs are efficiently dealt with as regards allocation of supplies, but transport difficulties interfere with regular deliveries. With regard to exports, fairly good despatches to our Allies are reported, but deliveries to neutrals are nil. For home consumption, No. 3 Cleveland pig, No. 4 foundry, and No. 4 forge all remain at 87*s.* 6*d.*, and No. 1 is quoted 91*s.* 6*d.* The export price of No. 3 is put at 97*s.* 6*d.*; that of No. 1 at 102*s.* 6*d.*; No. 4 foundry, 96*s.* 6*d.*; and No. 4 forge, 95*s.* 6*d.*

Hematite Iron.—Little new is ascertainable concerning the East Coast hematite branch of trade, but it is gratifying to learn that business is rather less difficult. Producers are not so unwilling to entertain suggestion on forward account as they have been for some time past. Home consumers are stated to be receiving adequate supplies, and some improvement in deliveries to our Allies, especially to Italy, are reported. For home use, Nos. 1, 2, and 3 are 122*s.* 6*d.*; for shipment to France, the price is 137*s.* 6*d.*; and for export to Italy, the quotation is 142*s.* 6*d.*

Furnaces in Operation.—The blowing-in of a blast-furnace on special iron increases the number in operation on the North-East Coast to 73, of which 28 are turning out Cleveland pig, 31 are producing hematite, and 14 are manufacturing special kinds of iron. Arrangements for the re-lighting of several more furnaces are now practically complete, and it is hoped that within the next week or two the number working will be increased by the blowing-in of two on Cleveland pig, one on hematite, and one on basic iron.

Stocks and Shipments of Pig-Iron.—The stock of Cleveland pig-iron in the public warrant stores here still stands at 4,434 tons, all of which but 36 tons of standard iron is No. 3 quality, there having been no alteration since the 23rd ultimo. Makers have very little stock available for sale. Shipments of pig-iron from the port of Middlesbrough so far this month are officially returned at 4,530 tons, as compared with 5,967 tons to the same date last month, and 10,110 tons for the corresponding part of November last year.

Coke.—Coke is in good request for local use, and values are maintained, notwithstanding the more than ample supply. The opinion prevails that the over-supply will be absorbed at an early date. Average kinds of blast furnace coke continue to realise 28*s.* at the ovens, and up to 30*s.* 6*d.* at the ovens is still asked for qualities low in phosphorus.

Foreign Ore.—Imports of foreign ore show some falling off, but they are still on a very considerable scale and the now very heavy stocks are stated to be still increasing. Unloadings at the port of Middlesbrough so far this month are officially given at 30,869 tons.

Manufactured Iron and Steel.—Producers of finished iron and steel keep very busily employed, mostly on Government work and on the output of mercantile shipbuilding material. Prices have been re-adjusted as regards extras, and export quotations have been revised. For home use common iron bars are 13*l.* 15*s.*; best bars, 14*l.* 2*s.* 6*d.*; best best bars, 14*l.* 10*s.*; iron ship plates, 13*l.* 10*s.* to 14*l.* 10*s.*; iron ship angles, 13*l.* 15*s.*; packing iron and steel (parallel), 11*l.*; packing iron and steel (tapered), 13*l.* 5*s.*; steel bars (no test), 14*l.* 10*s.*; steel ship plates, 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel boiler plates, 12*l.* 10*s.*; steel joists, 11*l.* 2*s.* 6*d.*; and heavy sections of steel rails, 10*l.* 17*s.* 6*d.* The following are the revised export quotations: Common iron bars, 15*l.*; iron ship plates, 14*l.* 10*s.*; iron ship angles, 15*l.*; steel bars, 16*l.*; steel ship plates (½-in. and upwards), 13*l.* 10*s.*, (⅜-in.) 13*l.* 15*s.*, (¼-in.) 14*l.*, (⅛-in.) 16*l.*, (½-in.) 20*l.*; steel boiler plates, 20*s.* above steel ship plates; steel ship angles, 11*l.* 2*s.* 6*d.*; steel sheets (singles), 20*l.*; steel sheets (doubles), 22*l.*; steel joists, 11*l.* 2*s.* 6*d.*; steel strip, 17*l.*; steel hoops, 17*l.* 10*s.*; heavy steel rails, 11*l.* 5*s.*; packing iron and steel (parallel), 12*l.*; and packing iron and steel (tapered), 14*l.* 5*s.*

NOTES FROM THE SOUTH-WEST.

Cardiff.—The outlook for steam coal is considered rather more favourable, the weather having improved and there being a prospect of larger arrivals of steamers. At the same time the commodity has remained depressed for prompt loading. A decision of the Norwegian insurance club to insure on French voyages has removed a difficulty and has resulted in Norwegian vessels again coming on the market. With excessive stocks it must take some little time to restore normal conditions, but while it has been possible to secure easy terms for delivery within the next week, colliery owners have been quoting firmly for the second half of November. House coal, coke, and patent fuel have shown little change. The best Admiralty large steam coal has been to some extent nominal; secondary descriptions have made 32*s.* to 34*s.*; Monmouthshire Black veins, 33*s.* to 34*s.*; ordinary Western Valleys, 32*s.* to 33*s.*; Eastern Valleys, 30*s.* to 32*s.*; best bunker smalls, 32*s.* to 33*s.*; and cargo smalls, 18*s.* to 20*s.* per ton. In bituminous coal best households have made 25*s.* 6*d* to 26*s.* 6*d.* at the pits; No. 3 Rhondda, large, 33*s.* to 34*s.*; smalls, 26*s.* to 28*s.*; No. 2 Rhondda, large, 28*s.* to 30*s.*; and No. 2, smalls, 20*s.* to 21*s.* per ton. The latest quotation for patent fuel has been 40*s.* to 42*s.* 6*d.* per ton. Special foundry coke has brought 62*s.* 6*d.* to 65*s.* for export; good foundry coke, 57*s.* 6*d.* to 60*s.*; and furnace coke, 47*s.* 6*d.* to 52*s.* 6*d.* per ton.

Western Trade Matters.—The projected new shipbuilding yard at Chepstow is being delayed in consequence of a scarcity of suitable labour; this is much to be regretted, as the promoters had secured ample orders.—The South Wales Miners' Federation, in view of high coal prices, demand an advance of 15 per cent. in wages; they urge that during the six months ended with September inclusive the average selling price of coal has risen 2*s.* 6½*d.* per ton and that miners have not received a proportionate advance in their remuneration.—The first sod has just been cut at Blaenau colliery, one of the new Saron drifts. These new drifts are in connection with the old Pwll-y-lard colliery, from which fine coal has been obtained in the past.—With reference to a renewed proposal (by the miners) for a joint audit in the South Wales coal trade, the coal owners intimate that they are prepared to allow the independent chairman of the South Wales Conciliation Board to appoint a chartered accountant to satisfy him that certain figures put forward by them correctly represent the working costs of South Wales collieries.—At a meeting of the Cardiff Chamber of Commerce the Chamber agreed, on the motion of Mr. Trevor Jones, that a letter should be addressed to the War Office setting forth the saving of time and expense on shipping chartered by the Admiralty which would be effected if Cardiff were made a first-class embarkation port under a recent War Office scheme.—A colliery decision of considerable importance has just been taken by the transfer of certain interests in the Glyncorrwg Steam Coal Company, Limited, belonging to Mr. J. Cory and his family, to their co-partner, Mr. W. H. Newton, chairman of the South Wales Coal Owners' Association, and also chairman of Lockett's Merthyr Collieries, Limited. The transaction is believed to be a personal and private purchase and not connected with Lockett's collieries. The Glyncorrwg Company is a private undertaking which owns an area of about 5,000 acres, with an annual output of 400,000 tons or thereabouts, the coal produced being steam and semi-bituminous. There are five pits, including a new sinking completed three years ago.—The Bathampton Steam Navigation Company, Limited, gives its shareholders a dividend of 30 per cent. for the financial year ended August 31. Three new steamers have been contracted for by this company, but their building has been much delayed by Admiralty requirements.—Presiding at a special meeting of North's Navigation Collieries (1889), Limited, Lord Rhondda said he had a confident belief, in view of the possibilities of the South Wales coal trade, that the company had a very valuable property; the undertaking went back nearly a century, but there was an enormous quantity of coal still to be worked.—The profits of the Orders and Handford Steam Navigation, Limited, for the year ended October, 1916, amounted to 55,584*l.*, after allowing 20,000*l.* for excess profits tax; the profits for 1915 were 64,477*l.*; for 1914, 12,845*l.*; for 1913, 30,402*l.*; and for 1912, 34,546*l.* The dividends for the five years came out thus:—1912, 20 per cent.; 1913, 15 per cent.; 1914, 7½ per cent.; 1915, 20 per cent.; and 1916, 25 per cent. Seven steamers owned by the company stand in the books at a little over 2*l.* 10*s.* per ton deadweight, while secondhand steamers were selling at 30*l.* per ton and upwards. The company's paid-up capital is 95,500*l.*; it has cash Government securities and investments to the amount of 200,836*l.*—Messrs. Percy Samuel and Co., managers of the Universal Steam Navigation, Limited, Cardiff, have purchased the management shares of the Kestell Steamship Company, Limited, Cardiff, and are making an offer through Messrs. Kestell Brothers for the purchase of any shares which shareholders may care to sell at the price of 100*l.* per 50*l.* share. The Kestell Company was formed in February, 1915.—The directors of the Ebbw Vale Steel, Iron and Coal Company, Limited, recommend an interim dividend at the rate of 6 per cent. per annum upon the preference shares for the half-year ended September 30.—Mr. A. Michelson has been elected on the directorate of the Atlantic Trust, Limited.—The South Rhondda Colliery Company, Limited, has divided its 6,000 shares of 10*l.* each into 60,000 shares of 1*l.* each.—The shares in the Mannesmann Company have been acquired by British interests. The company has made arrangements to go on with its Newport undertaking, and the Government has sanctioned the raising of the necessary capital.—The Swansea Town Council recently extended invitations to high Australian officials to visit the district and inspect the facilities which it affords for the treatment of Australian ores. The invitation was accepted by the Agent-General for Victoria (Sir P. McBride), Mr. F. M. Young (South Australia), and the Agent-General for Western Australia (Mr. M. L. Moss).—On Saturday Messrs. Hansen Brothers, Limited, shipowners, Cardiff Docks, completed arrangements for the purchase from Messrs. Pyman, Watson and Co., Limited, Cardiff, of four steel screw steamers of 14,000 tons deadweight. The vessels were part of the fleet formerly owned by the London Northern Steamship Company, Limited.

A NEW NIAGARA BRIDGE.—The Ontario and Niagara Connecting Bridge Company is to build a bridge of steel and concrete over the Niagara at Niagara Falls. The bridge is to be available for steam and electric railways, vehicles and pedestrians; its cost is estimated at 200,000*l.* The structure will span the Niagara near a point at which the transmission line of the Niagara, Lockport and Ontario Power Company crosses the rapids.

THE ARGENTINE NAVY.—We read in the *Rivista Marittima* that the battleship Rivadavia has been somewhat damaged by grounding in the port of Bahia Blanca, and will have to return to the Fore River yard for repairs; these will include the reconstruction of some of her machinery and its foundations. Owing to the sinking of the floor of the masonry basin at Bahia Blanca, built for careening the Rivadavia and Moreno, there is no dock yet available in Argentina for taking either of these new battleships.

ENEMY FIRM IN FIJI.—The Colonial Office notify, through the Commercial Intelligence Branch, Board of Trade, that creditors of the firm of Hedemann Evers and Co., of Levuka, Fiji, which has been ordered to be wound up under the Alien Enemy Trade Disposal Ordinance, 1916, are required to send their names and addresses and full particulars of their debts and claims, together with the names of their solicitors (if any), to the liquidator, Mr. Arthur Joske, of Suva. These particulars must be furnished on or before February 28 next. The proofs of creditors outside the colony of Fiji must be accompanied by a statutory declaration that the debt is due and owing, with particulars as to securities (if any) held, and must show how the order for goods was given. The statutory declaration must further state whether there have been prior dealings with the said company, and, if so, how payment was previously made. All creditors of the above-mentioned company may prove in the liquidation, but those creditors who have looked for payment to the Hamburg office of the company or to any branch of that office outside the colony of Fiji, will not receive any dividend, or be allowed to rank for dividend, until all claimants who have dealt directly with the Fiji firm, and who have looked exclusively to that firm for payment, have been paid in full.

SIDE-PLANING MACHINE AND BORING AND TURNING MILL.

CONSTRUCTED BY MESSRS. GEORGE RICHARDS AND CO., LIMITED, BROADHEATH, MANCHESTER.

(*For Description, see Page* 457.)

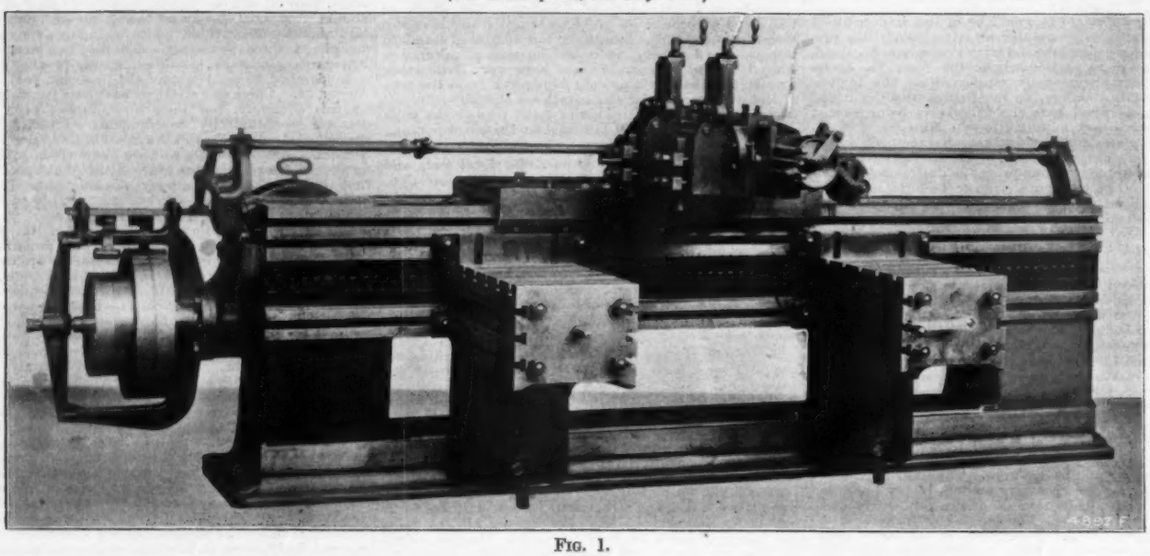


FIG. 1.

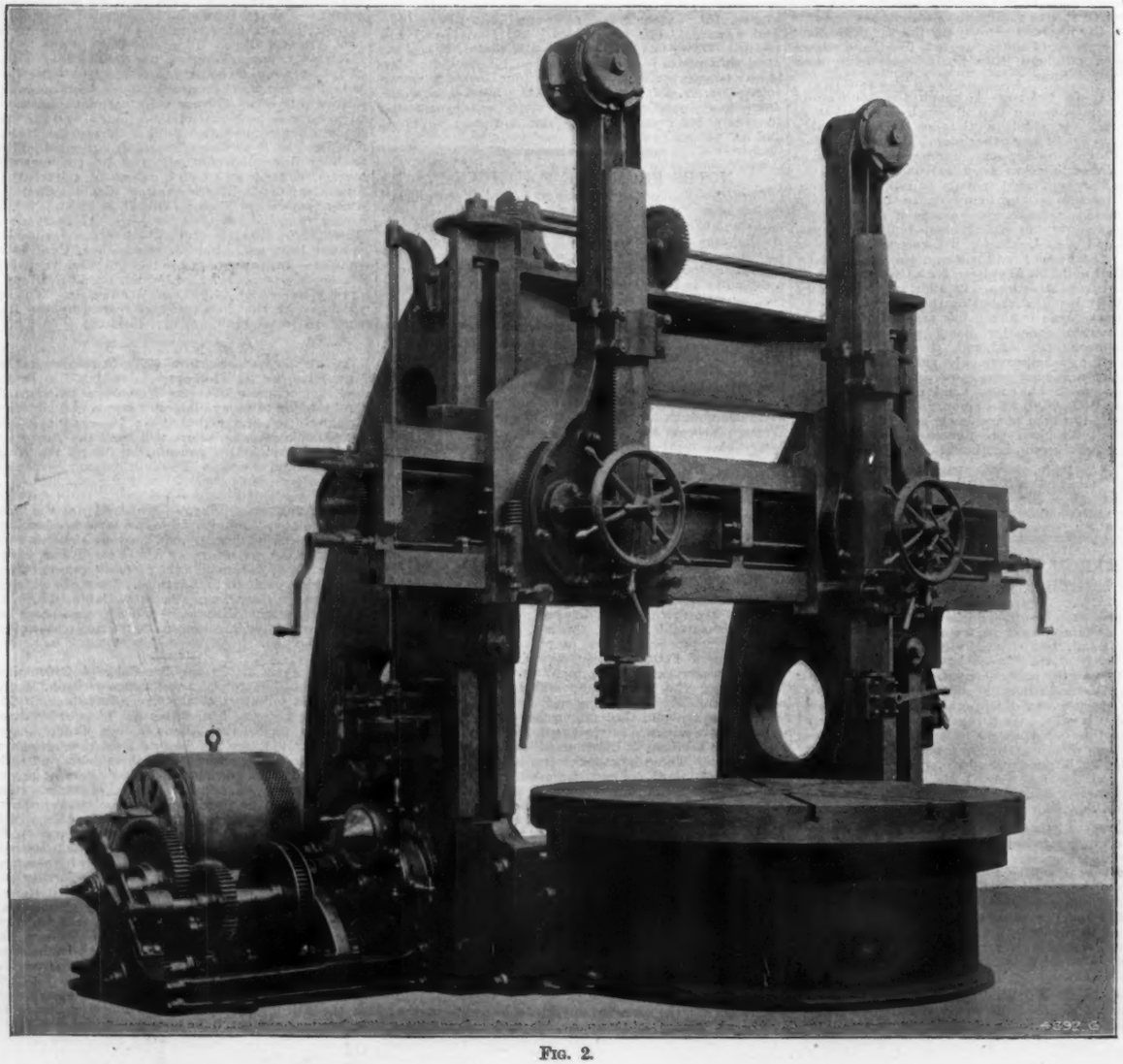


FIG. 2.

DETAILS OF 9,000-GALLON TENDER; PENNSYLVANIA RAILROAD.

MR. J. T. WALLIS, GENERAL SUPERINTENDENT OF MOTIVE POWER.

(For Description, see Page 452.)

Fig. 239.

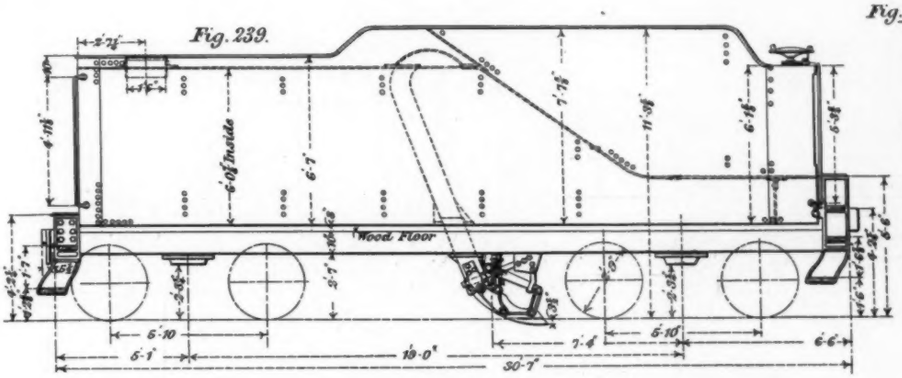
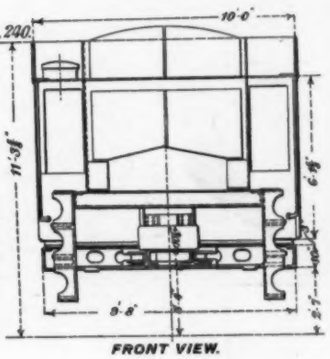


Fig. 240.



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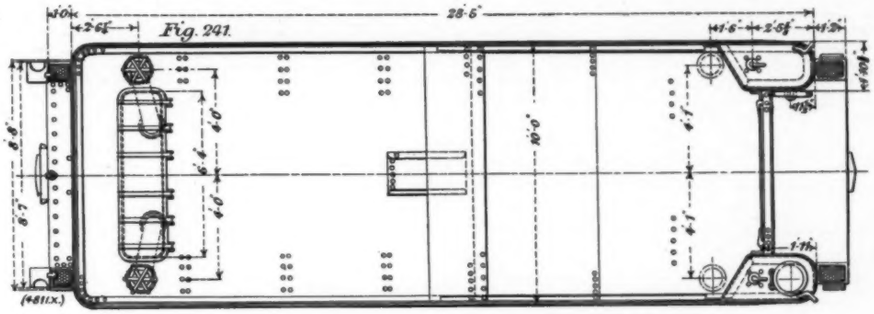


Fig. 242.

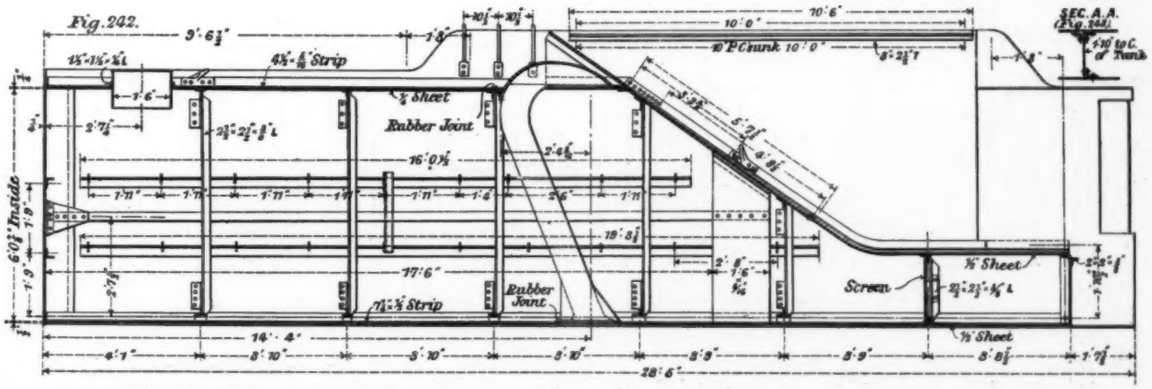
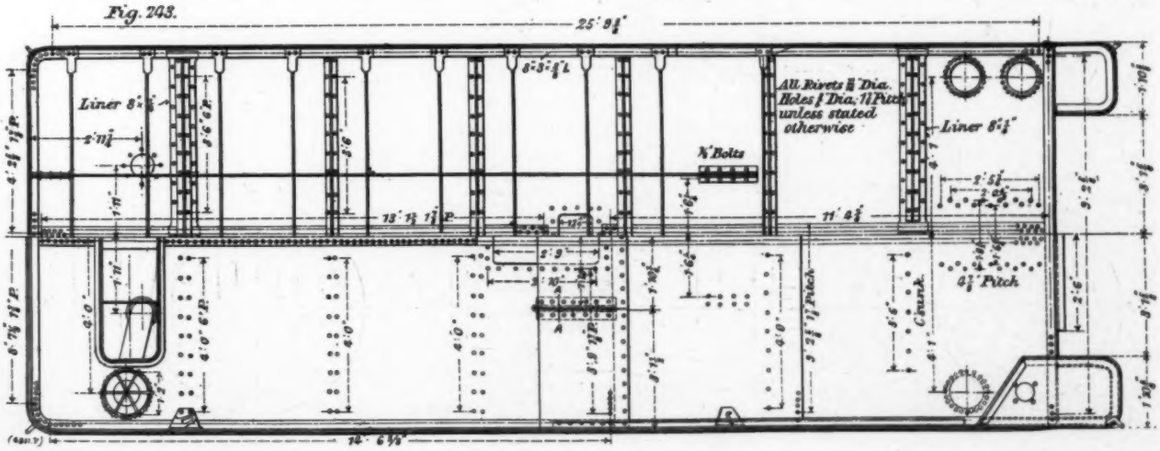


Fig. 243.

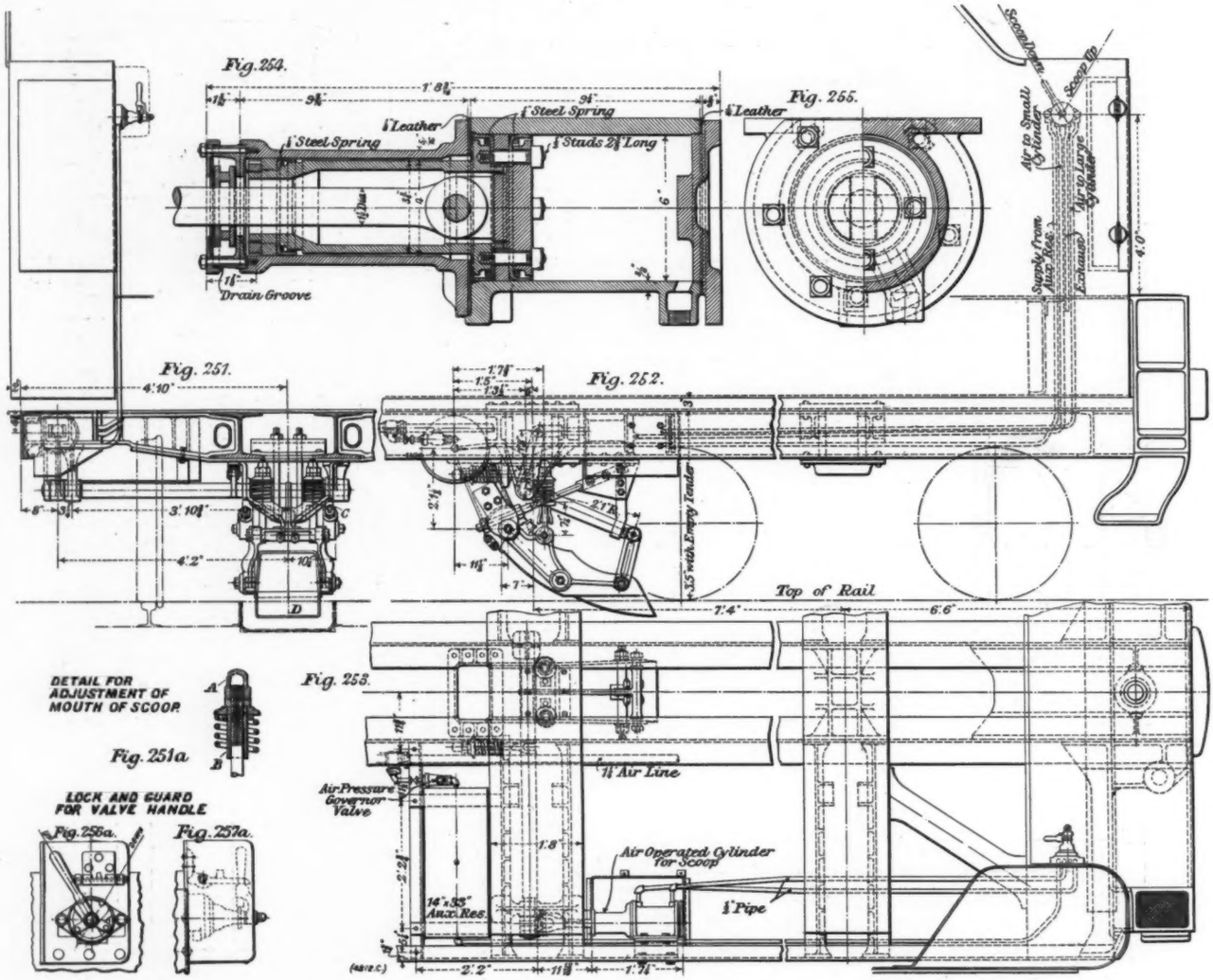


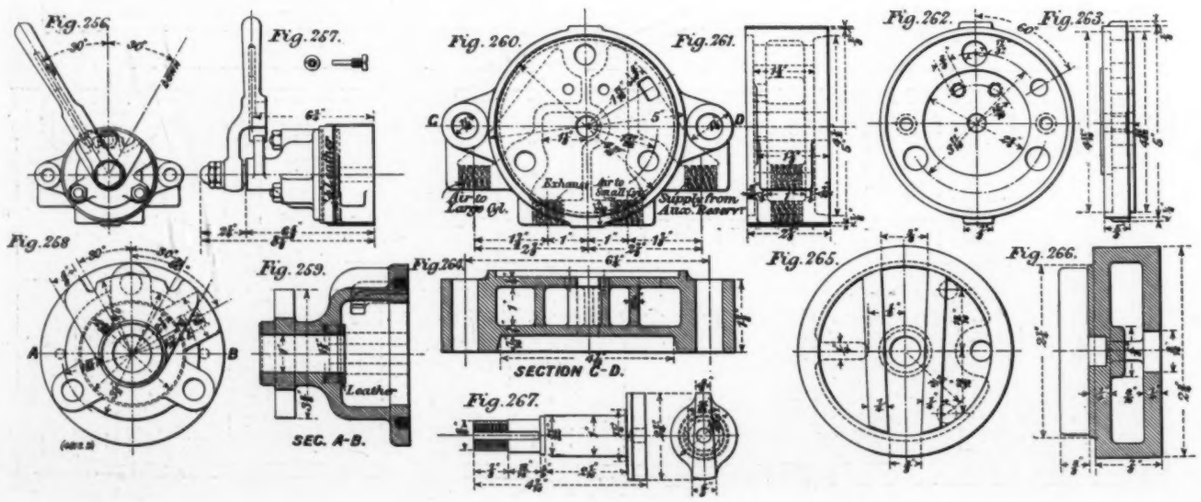
(To face page 452.)

DETAILS OF 9,000-GALLON TENDER; PENNSYLVANIA RAILROAD.

MR. J. T. WALLIS, GENERAL SUPERINTENDENT OF MOTIVE POWER.

(For Description, see Page 452.)





ENGINEERING WORKS OF THE FIAT SAN GIORGIO COMPANY AT TURIN.

(*For Description see Page* 453.)

Fig. 1. Machine Shop for Work of Medium Size in the Southern Section of the Works.

Fig. 2. Another View of the Machine Shop for Medium-Sized Work.

ENGINEERING WORKS OF THE FIAT SAN GIORGIO COMPANY AT TURIN.

(*For Description, see Page* 453.)

FIG. 3. MACHINE SHOP FOR LARGE INTERNAL COMBUSTION ENGINES.

FIG. 4. GALLERY FOR LIGHT WORK ON LARGE INTERNAL COMBUSTION ENGINES.

(*To face page* 453.)

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Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than 1 p.m. on Tuesday in each week.

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Foreign and Colonial subscribers receiving incomplete copies through newsagents are requested to communicate the fact to the Publisher, together with the agent's name and address.

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TELEPHONE NUMBERS—3063 and 8598 GERRARD.

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With Two One-Page Plates of DETAILS OF 9,000-GALLON TENDER, PENNSYLVANIA RAILROAD; and Two One-Page Plates of the ENGINEERING WORKS OF THE FIAT SAN GIORGIO COMPANY AT TURIN.

NOTICES OF MEETINGS.

THE PHYSICAL SOCIETY OF LONDON.—Friday, November 10, at 5 p.m., at the Imperial College of Science, Imperial Institute Road, South Kensington, S.W. Agenda: (1) "Note on the Diffusion of Liquids," by Mr. B. W. Clack, M.Sc. (2) "The Regularity in the Distribution of the Satellites of Spectrum Lines; with a Note on the Structure of the Green Line of Mercury and Terms of Correction in Using a Concave Grating," by Professor H. Nagaoka.

THE KEIGHLEY ASSOCIATION OF ENGINEERS.—Saturday, November 11, in the Assembly Room of the Cycling Club. Subject: "Some Modern Developments in Steam Engine Practice," by Mr. Wm. Eastwood, M.I.Mech.E., Assoc.M.Inst.C.E. Chair to be taken at 6.45 p.m. by Mr. Alfred Baldwin.

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.—Saturday, November 11, at the Institute, Wolverhampton Street, Dudley, when the President, Mr. J. E. Fletcher, M.I.M.E., will deliver his Presidential Address. Chair to be taken at 7.15 p.m.

THE MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.—Saturday, November 11, at 3.30 p.m., at the Danum Hotel, Doncaster. The following paper will be read:—"Making a Shaft Upwards," by Mr. George Blake Walker. The following papers will be open for discussion:—(1) "Earth Movements in the South Yorkshire Coalfield," by Professor W. G. Fearnsides, M.A., F.G.S. (2) "Fuel Economy at Collieries," by Mr. F. F. Mairet. (3) "Health of Old Miners," by Dr. Haldane.

THE SURVEYORS' INSTITUTION.—Monday, November 13, when the President, Mr. George Francis Stewart, will deliver an opening address. The chair will be taken at 5 p.m.

THE INSTITUTION OF ELECTRICAL ENGINEERS: MANCHESTER LOCAL SECTION.—Tuesday, November 14, at 7.30 p.m., in the Engineers' Club, Albert Square, Manchester, when the chairman, Mr. A. E. McKenzie, will deliver his address.

THE INSTITUTION OF ELECTRICAL ENGINEERS: SCOTTISH LOCAL SECTION.—Tuesday, November 14, at 7.30 p.m., in the Rooms, 207, Bath Street, Glasgow, when the chairman, Mr. J. K. Stothert, will deliver his Inaugural Address.

THE INSTITUTION OF ELECTRICAL ENGINEERS: BIRMINGHAM LOCAL SECTION.—Wednesday, November 15, at 7 p.m., at the University, Edmund Street. The Kelvin Lecture will be delivered by Dr. A. Russell.

THE ROYAL SOCIETY OF ARTS.—Wednesday afternoon, November 15. The opening address of the 163rd Session of the Society will be delivered by Dr. Dugald Clerk, D.Sc., F.R.S., Chairman of the Council. The subject of the address will be "The Stability of Great Britain." The chair will be taken at 4.30 p.m.

THE ROYAL METEOROLOGICAL SOCIETY.—Wednesday, November 15, at 5 p.m., at 70, Victoria Street, Westminster. Papers to be read:—(1) "A Meteorologist in China," by Mr. C. E. P. Brooks, M.Sc., F.R.Met.Soc. (2) "The Storm of the 11th-13th November, 1915, in its Passage over the British Isles," by Lieut. A. E. M. Geddes, R.E.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, November 17, at 6 p.m., at the Institution of Civil Engineers, Great George Street, Westminster. Paper on "Report of the Hardness Tests Research Committee.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.

ENGINEERING.

FRIDAY, NOVEMBER 10, 1916.

SCIENCE AND ENGINEERING.

NOWADAYS, when so much stress is quite properly and appropriately being laid on the prime importance of a greater application of science to industry, it is perhaps just as well that someone of eminence should call attention anew to the fact that engineering is not now, and presumably never will be, one of the exact sciences. This theme constitutes perhaps the dominant note of the interesting and suggestive address delivered last Tuesday by Sir Maurice Fitzmaurice as President of the Institution of Civil Engineers. In their enthusiasm for a much belated and badly needed reform, many of its advocates have exaggerated the ease of the transition from the science of the laboratory to its practical applications, and there is perhaps some danger of those who control our industries being led to believe that the engagement of a scientific staff and the expenditure of no very substantial sum in experiment will result almost immediately in astonishingly substantial returns. Certainly the prospect is a fair one—the ground has long been inefficiently worked. Indeed, the view that sound policy consisted in never taking up a new departure until it was well past the experimental stage has been far too widely held either for the national good in general or that of the engineering profession in particular. This section of the community would rather pay thousands in royalties to some enterprising foreigner who would tell them how he had himself mastered certain pioneering difficulties, than hundreds in developing a new idea on their own account.

Men with such views have of recent years been the bane of British industries, and there is little doubt that the narrow specialisation in the study of dead languages prevalent in this country has been largely responsible. Matters have been rendered still more difficult by the growth of limited liability companies, the shares of which have been held in the main by those suffering similarly from a seriously defective education. The relatively low rate of manufacturing profits over a long series of years has emphasized this drawback.

Sir Charles Parsons has expressed the opinion that for an engineering works to maintain a leading position at least 1 per cent., and preferably 3 per cent., of the annual turnover should be devoted to experiment. A large proportion of such experiments are, in the nature of things, doomed to failure, and it is difficult to make half-educated shareholders understand that these abortive investigations represent anything but ignorance and incompetence on the part of the management. Where a public authority is concerned, matters are still worse. Any such failure becomes forthwith a useful political weapon, and municipal and Government engineers have accordingly to be exceedingly cautious in any departure they venture from well-beaten paths.

Possibly the president's address may be open to the objection of confirming a certain school of critics in the belief that engineers as a body are hopelessly unscientific in their methods and ideas. The most eminent member of this school is probably Professor Henry Armstrong, who, from an address delivered last spring to the Junior Institution of Engineers, would seem to be under the impression that engineers construct harbours on stormy seas, erect safe buildings on doubtful foundations, or develop the art of flight without ever in the course of their researches defining the nature of the particular issue to be inquired into, and without having clear and definite views as to the motive or purpose of any investigation or experiment on which they may embark. In the old school laboratories it was the custom of ingenuous youth to mix together a little of every reagent present, actuated by some sort of faint hope that he might thus achieve some notable discovery. Apparently Professor Armstrong holds the view that this has been, in essence, the practice of the engineer in the past, and this misconception is no doubt largely responsible for his desire that engineering students should waste time in the study of chemistry by heuristic methods. The presumed advantage of this system is that the student is compelled to think, but original thought has to be exercised by every draughtsman who schemes even the lay-out of a new shop, let alone those who have to solve the more difficult problems that arise in practical engineering.

Probably engineers as a body are less in need of an academic heuristic training than any section of the community. Sir Maurice Fitzmaurice in his address, instanced case after case in which the engineer is compelled by the nature of things to risk huge sums of money on data which are unavoidably far from complete. On the whole, he is remarkably successful, and this success is secured because he applies the methods of science to the problems before him. During sleepless nights and laborious days he ponders over every factor which can in any conceivable way affect the matter, and, so far as circumstances permit, tests by observation and experiment each provisional hypothesis formed.

Indeed, the word science, as applied to engineering, is often used in far too restricted a sense. Frequently it is taken as synonymous with the application of mathematical analysis to questions of engineering design. Where this is possible, advance is generally very rapid, as instanced by the remarkable growth of electrical engineering during the past quarter of a century. The more accurate analysis of stresses in structures has also led to great improvements in structural steel work, but unfortunately there is no such close connection between the mathematical theory of elasticity and structural strength as exists between theoretical and applied electricity. This circumstance was no doubt in the main responsible for the unedifying failures of the giant cranes supplied to Barrow and to Panama by the Deutsche Maschinen-Fabrik, A. G. Dinaberg, and was also in part responsible for the catastrophe in connection with the first Quebec bridge.

There are other cases in which a too assured

reliance on what is commonly termed science would have barred progress. Professor Fleming has described the anxiety with which he and Mr. Marconi gazed out over the Atlantic and debated the possibility of transatlantic radiography. America, they realised, lay not so much before them as below them, and what was then known as to the theory of electric waves did not encourage the view that they would get round the arc. The theory of elasticity provides another instance in kind. Computation on this basis indicates the existence of enormous stresses at the foot of the arched dams of which a considerable number have been erected in New South Wales and have proved cheap and satisfactory. Was the engineer more or less scientific in rejecting what is commonly called science in this instance, and relying on his common-sense and his knowledge of the actual properties of materials? What American or German engineers would call a more scientific type of dam would have cost perhaps three times as much, and though nominally far less stressed there is no reason to believe that it would be in any way safer.

It is not, however, merely the mathematical sciences which have occasionally proved defective when applied to practical engineering problems. In the address to which we have already alluded Professor Armstrong makes the astounding statement that the work of the Rivers Commission, to which he was at one time attached, "led to an almost complete abolition of sewage-infected drinking water from this country." As a matter of fact, sewage-polluted sources supply the water drunk by a very large proportion of the inhabitants of the kingdom, and experience shows that, in the case of large towns, at any rate, their standard of health is generally better than that of the population of towns relying on so-called uncontaminated supplies. Had the engineer been guided by the ignorant chemist of 40 years ago, the cost of our water supplies would have been largely increased, and the rate of mortality from water-borne diseases notably augmented. The classical case is, of course, that of Hamburg and Altona in the cholera epidemic of 1892. Altona drew its water from the River Elbe, the intake being actually below the outfall from some of the Hamburg sewers, yet, whilst there were over 16,000 cases in Hamburg, and over 8,000 deaths, Altona was free from all but imported cases. The explanation lay in the fact that whilst Hamburg, taking its supplies from far up-stream, relied on their native purity, Altona realised that its water, as drawn from the river, was badly contaminated, and treated it, accordingly, by the process of slow sand filtration, devised some three-fourths of a century ago by Mr. James Simpson. This process, invented in the days when even the germ of the germ theory of disease lay in the still distant future, was intended merely to clarify the water, but as subsequent experiment has shown, effected far more, rendering it almost biologically pure.

These instances emphasise the necessity of the engineer being so far as practicable his own scientist, and it is therefore most important that he should acquire in his student days as wide a knowledge as possible of scientific principles. For our national neglect to apply science to industry, the financier and capitalist have been far more to blame than the engineer. These powers behind the throne are again in the main responsible for the fact to which Sir Maurice Fitzmaurice draws attention, that in America money is much more freely expended in preliminary investigations than is the rule here. The preliminary studies for the new Quebec Bridge, for example, are said to have cost 100,000*l.*

COMPARISON OF TOWN PASSENGER TRAFFIC SYSTEMS.

A most interesting comparison of all possible systems of passenger traffic on streets in large cities is made in a report to the Edinburgh Corporation by Mr. John A. Brodie, the City Engineer of Liverpool, Mr. J. B. Hamilton, the General Manager of the Leeds Tramways, and Mr. A. Horsburgh Campbell, Burgh Engineer of the City of Edinburgh. They were asked by the Corporation to report on the tramway system of the city in view of the termination of the lease on June 30, 1919, of the existing tramways, which are operated, so far as the central part of the city is concerned, by cable, while the outlying parts are on the overhead electric system. It will not surprise many that they have come to the conclusion that the electric overhead system is to be preferred before all others, especially when it is noted that of the 2,724 miles of street tramway in the United Kingdom less than 1 per cent. is on other systems, and more than half of the exceptional lines are due to the London conduit system. This latter system, departed from on new lines by the London County Council, has, as is stated, the disadvantages of high constructional cost, the presence of longitudinal centre rails and slots, less reliability of working, and greater cost of maintenance. The relative cost of the permanent way and electrical equipment of the overhead system is estimated at 16,000*l.* per route-mile of permanent way having double tracks, as compared with 34,000*l.* for the conduit system, and this, in the case of the moderate length system in Edinburgh, would mean an expenditure of 400,000*l.* only instead of 850,000*l.* These figures are exclusive of power plant, depots, rolling stock and feeders. Operating expenses, too, show a very considerable increase in the case of the conduit system. The surface contact tramway system, which is in operation at Lincoln and Wolverhampton—a short line in London and one at Mexborough having been superseded—is also dismissed because of certain "disadvantages which render it unsuitable to the complete service of such a city as Edinburgh." These, however, are not analysed in the report.

The alternative of self-propelled tramcars, which were considered principally because they might form an adjunct to the existing cable system for through city traffic, was also rejected, although there are in operation in this country five lengths of line, all very short with the exception of the Dublin and Blessington Light Railway of 20 miles. The self-propelled tramway car is usually advocated because of its resemblance to the motor 'bus, but it is pointed out in the report that the weight of a motor 'bus is in the proportion of 280 lb. per passenger to the 373 lb. per passenger of a self-propelled tramcar. The system of central power generation and transmission for the overhead or conduit electric system provides greater reserves of current to meet greater variations of load. Electric cars operated either by overhead or conduit traction in Edinburgh would each be fitted with two motors of 45 horse-power, capable of developing 100 per cent. overload for considerable distances, whereas the self-propelled car would require a 90 h.p. internal combustion engine. The general consumption of petrol for a 40 h.p. engine is stated at about one gallon of petrol to every seven car-miles or thereabouts. There would also be very heavy repairs for petrol engines. Thus the conclusion come to is that the total operating expenses would be at least 2*d.* per car-mile above that of electric overhead traction. The cost of the car itself for the overhead system would be 950*l.* and for the self-propelled system 1,250*l.* But in addition there would require to be a greater number of spare cars, probably 10 per cent. more, efficiently to maintain and assure the same service as with electric cars. Thus in the case of Edinburgh the additional cost for the cars would be 96,250*l.*, but there would be saved the 55,000*l.* involved in the overhead electric equipment. Neither on the score of efficiency nor operating cost is the self-propelled tramcar commended. Were it decided to continue the cable traction system for the centre of the city, experiments with self-propelled cars are recommended before settling whether this system would be a success. A similar trial of an electric battery tramcar under the same circumstances is suggested, but the report states that "we are not sanguine of its adoption as the sole method of traction for any large tramway system."

The claims of the motor 'bus are also considered, and they are not commended. The carrying capacity is only 50 per cent. of that of each tramcar, and consequently there would be required a much greater number, resulting in undue crowding of the streets. The tramways would yield to the rates of the city on the present basis 15,389*l.*; and motor 'buses only 1,616*l.* The tramway undertaking would maintain a large part of the road surface, while the motor 'buses would probably involve an extra wear and tear of the city roads to the extent of 4,000*l.* per annum in the case of Edinburgh. These losses and charges, direct and indirect, to the city represent a difference in favour of tramways of 39,425*l.* The success of the 'buses in London is considered to be due to entirely unique conditions, in which the contour and condition of the road enter largely. The motor 'bus, however, might become a serviceable and suitable auxiliary as a feeder to the tramway system.

The presence of the conduit for the existing cable suggested that this might be used for the electric conductors, but it is pointed out that it is quite inadequate in area, the London electric conduit being exactly double the sectional area and the Paris conduit 2.4 times that of the Edinburgh cable conduit. Thus a new conduit would require to be put in, and apart altogether from the financial condition this would involve discontinuity in the operation of the tramways during reconstruction. On the other hand, the overhead electric system could be constructed while the cable tramways were running, twin-wiring being used for completing the electric circuit pending the bonding of the rails, which could be done after the lease expired. One other question of importance has reference to gradients. In Edinburgh there are six gradients varying from 1 in 12 to 1 in 16, but it is pointed out in the report that in Leeds there is a gradient of 1 in 8.42, in Huddersfield 1 in 9.30, in Sheffield 1 in 9.5, in Halifax 1 in 9.7, in Bradford 1 in 10, in Dundee 1 in 11.14 and in Liverpool 1 in 14, so that on this score no difficulty presents itself in the application of the overhead electric system.

The æsthetic question necessarily bulks much in the problem. One does not need to write of the beauty, especially of Princes Street, and although there are now many telephone and telegraph wires overhead, it would be a great misfortune if the beautiful vistas in this thoroughfare were in any way affected by overhead wires. There is, however, the great importance of through traffic not being interrupted, and we think the report offers a satisfactory solution, based on the procedure along the Thames Embankment. It is proposed that along Princes Street the tramway lines should be close to the kerb on the south or garden side of Princes Street, that the overhead wires should be carried on brackets supported on standards rising from the kerb, and so arranged that their unseemliness would be hidden or lessened by the foliage of the trees along the footpath.

THE GAS ENGINEER OF THE LAST CENTURY.

The present lighting restrictions bring home to us in some degree the conditions under which our grandparents made their walks abroad after dark. The want of light in their case was not due to Government interference, but to the great cost of all illuminants. What this was at the commencement of the nineteenth century is not certain, but as late as 1841 Dr. Ure mentioned that sperm oil cost 9*s.* per gallon, and it is quite probable that this—the sole means of outdoor illumination—was still dearer at the beginning of the century. It is certain that street lights would be few and far between, while the troubles of the pedestrian would be increased by the poor paving, or entire want of paving, and by the frequent presence of footpads. No wonder that gas was received with enthusiasm, although one impecunious literary man lamented that it rendered it more difficult to avoid the sheriff's officers. The first street gas lighting in London was in 1804, and was followed by Parliamentary schemes in 1809–10–12–14 for the National Light and Heat Company, afterwards the Chartered Gas Company, now the Gas Light and Coke Company, of London. By 1827 the whole of the public oil lanterns of London were replaced by gas lamps. Probably these did not give very much light, judged by our present ideas, for the price of gas was originally 15*s.* per 1,000 ft., and from 1837 to 1849 it was 6*s.*, as against 2*s.* 2*d.* in 1909. It is only fair to say, however, that the early gas was very rich, and that burners consuming 1 cub. ft. per hour satisfied a public accustomed to tallow candles.

The early progress of gas lighting was slow, mainly, we imagine, because the houses were not piped for its reception and that tenants and land-

lords each tried to put the expense on the other. We have seen the same struggle in recent years in connection with electric wiring. It could scarcely have been the quarterly bills which deterred householders, for they could not have exceeded the cost of tallow candles at 8*d.* per lb., or wax candles at 2*s.* 6*d.* per lb., unless the illumination had been greatly increased. Gasworks multiplied in London faster than the demand grew. In 1823 the output by the Chartered Gas Company was 660,000 cub. ft. daily, but there were several other companies. In 1837 the total annual consumption in the Metropolis was 1,600,000,000 cub. ft., and this doubled in the period 1837–1849. The amounts for the decennial periods 1869–79–89–99, 1909, were 9,885,000,000, 17,635,000,000, 20,649,000,000, 34,057,000,000 and 38,300,000,000. In 1915 the consumption was 42,624,000,000 cub. ft.

Gas lighting was, of course, not confined to London, and in 1850 there were 750 established gas companies in the kingdom. These represented an immense amount of engineering work, both in the distillation of the coal and in the distribution of the gas. Prominent among the men who directed the progress of the art was Mr. Thomas Hawksley, who was engaged in the design of gasworks from 1830 to 1893. It was therefore very fitting that the Thomas Hawksley Lecture before the Institution of Mechanical Engineers should this year be devoted to a recital of the work of the gas engineer of the last century.

The lecture was delivered last Friday (the 3rd inst.) by Mr. Harry E. Jones, whose long connection with the Gas Light and Coke Company of London rendered him peculiarly fitted to undertake the task. He selected three names, from a crowd of others, as specially worthy of note in connection with the rise and progress of the gas industry. These were Samuel Clegg, Thomas Hawksley and George Livesey. Clegg was both a capable engineer and an inventor; he was engaged in putting up gasworks under Murdoch as early as 1806, and as late as 1850 he was writing vigorously to the *Journal of Gaslighting* vindicating his claim to the invention of the wet meter. There is no doubt that he did more than anyone else to convert the early crude appliances into commercial plant capable of giving satisfactory service to the public. The invention of the wet meter, and of the hydraulic seal in retort mains, valves, purifier covers and gas holders, are all credited to Clegg. A very interesting and important figure, he stands out pre-eminent in practical work of value for the first 25 years of the development of gas.

When Hawksley began practice as a gas engineer much of the pioneer work was done, and it was in the arrangement of works as a whole, rather than in the perfecting of the individual appliances, that he engaged. No one who knew him needs to be told that his work was splendid, and that completeness, rather than economy, was the object he kept in view. Mr. Jones says that his early works were "of Roman endurance," due partly to nervousness on the part of the public on account of various explosions which had taken place, and largely, no doubt, to his natural tendency to eliminate every chance of breakdown. It must not be supposed, however, that Hawksley had in his early days only to assemble machinery already in the market. He had to teach his various contractors in all the specialities, such as retort setting, gas-holder and tank construction, as well as in purification plant. This involved a large amount of labour, and would have engrossed the whole attention of most men. But Hawksley is better known as a waterworks engineer than as a gas engineer, and in addition occupied a leading position as a sanitary engineer. His labours covered all phases of town life.

The third of the three great gas engineers is Sir George Livesey, who covers the period from 1865 to 1908. He was connected with the South Metropolitan Gas Company, and executed some of the largest works in existence. The East Greenwich Works, which he designed, have a daily output of 30,000,000 cub. ft. They comprise jetties, viaducts, wharf walling, deep tanks, and the loftiest gasholders yet ventured upon in this country, extensive carbonising retort buildings and special purifying plant, a tar distillery, sulphuric acid works, and plant for following up all the ramifications and labyrinths of the enormous family of secondary by-products arising from gas manufacture. He encountered and conquered serious difficulties in deep foundations, sand pumping and grabbing through water-bearing strata, and the construction of deep tanks in unstable water-logged soils, under heavy pressure from neighbouring main river channels. He is, perhaps, best known for his courage in fighting a gigantic strike, and for the wise statesmanship by which he subsequently reconciled labour to the interests of capital by a scheme of co-partnership, which comprised the admission of workmen to the board of directors. He devised the sliding scale for the price of gas, and effected the removal of many vexatious and useless restrictions on the manufacture imposed by Parliament. He put the industry on a new footing by insisting that the interests of the consumers and of the companies were, if not identical, at least not antagonistic.

We have, then, three very different types of engineers covering the period from 1806 to 1908, and representing also the advance of engineering science and practice in that period. First, we have the mechanic and inventor who worked out the plant from its early crude condition into one of practical use. Next comes the scientific engineer, who put the manufacture on to a sound commercial basis. He was the servant and friend of the capitalist, piloting his schemes through Parliament, and then giving them a material existence in which they would be certain to earn steady dividends. Finally comes the engineer-statesman, who was not only an engineer of things, but also an engineer of men. He moulded the laws and social usages of his time, and left the body politic in a condition to work more sweetly and efficiently than he found it. Livesey's economic achievements have somewhat obscured his work as an engineer. That alone would have been a monument for most men, for nearly everything he did was a step in the dark. It was not only that his constructions in gas plant and works were larger than their predecessors, but they exemplified novel principles, and required not only great engineering knowledge for their design, but, what is more rare, moral courage of a high order for their construction.

As to the numerous other engineers who deserve honourable mention in connection with the gas industry we must refer our readers to Mr. Jones's lecture, which will be printed in the Journal of the Institution. They will there find a very valuable record of the rise and progress of gas lighting, and of the men who took part in it. We cannot help feeling, however, that the monopoly which the industry enjoyed, valuable as it was in the early years, had a deadening tendency in the middle of the century, and that progress would have been more rapid had it earlier felt the stimulus of competition. From 1804 to 1850, when Young introduced paraffin oil, gas had no more serious competitors than the candle and the sperm oil lamp. The discovery of petroleum in large quantities in America was an enormous boon to the poor and to dwellers in the country. But it did not greatly affect the sale of gas in towns, and the monopoly was not seriously threatened until the advent of electric light. The lighting of the Avenue de l'Opera in Paris by the Jablochkoff candle in 1878 sent a cold shudder down the back of the gas shareholder, while acting as a tonic to the gas engineer. Before that date scientific discovery had generally strengthened the position of the gas company. The discovery of the aniline dyes in 1858 and the great appreciation of the value of ammonia as a manure some years later had increased the value of residuals enormously, and had rendered efforts at economy of manufacture a counsel of perfection. The introduction of the Swan lamp about 1880 entirely reversed this process. Since then one improvement has followed another in rapid succession, the last 20 years of the century seeing the introduction of the Welsbach incandescent mantle, the penny-in-the-slot meter, new methods of purification, high-pressure mains, in addition to numerous improvements in the works. The gas engineer has certainly fought a strenuous battle on behalf of his shareholders, and there is every prospect that in the twentieth century he will more than rival the achievements of his predecessors in the century dealt with in Mr. Jones' interesting lecture.

THE ACCIDENT TO THE QUEBEC BRIDGE.

By Frank W. Skinner.

(*Concluded from page* 444.)

Condition of the Hoisting Apparatus after the Accident.—Although the principal effects of the accident were confined wholly to the wrecked suspended span, and no traces whatever are visible on the cantilever arms, anchor arms or substructure, the photographs, observations of witnesses, and the traces left on the hoisting yokes give sufficient facts that, when properly interpreted, clearly and indisputably show the sequence of events and the cause of the accident.

As soon as possible after the accident occurred a minute examination was made, notes and measurements recorded, and photographs taken of the hoisting apparatus, and particularly of the bearings on the lower girders that supported the suspended span. These were made by the Government officials and the engineers of the bridge commission and of the contractors, and by a representative of *Engineering News*. They were all concurrent, and the investigators unanimously agreed in their interpretation of the facts observed.

Accurate levels taken show that the cantilever arms have regained their previous elevation before the accident. The hydraulic jacks and pumps were found entirely uninjured and in perfect order except for slight displacement of some of the light pipes connecting them. The four sets of lifting yokes were in position, unbroken and only slightly distorted by the tremendous stresses to which they had been subjected. The mooring trusses for mooring the span were practically uninjured, though the lines connecting them to the spans had not been cast off but were broken and had severely stressed the trusses when the span fell.

As soon as possible after the accident the examining engineers and the official photographer were lowered by derricks from the cantilever arms to examine the hoisting girders suspended about 25 ft. above low-tide level. The principal injuries noted were as follow :—*

At South-West Corner, where Failure Originated.—At the south-west corner the lower rocker pin remained in position on the lower casting, but had rotated towards the east on its axis and was scored. The lead bearing was pressed out from under the lower casting, and the cover plate of the box girder was bent and scored in a north-east direction at an angle of 45 deg. with the bridge axis on the north side east of the centre of the girder. The angles riveted across the top flange of the girder to receive the temporary bridle that suspended the girder in transit were cut through their vertical flanges at an angle of about 45 deg. and bent downward on the east side, where the suspension bridle was gone, and on the west side the bridle was crushed down and carried to the east. The north-west centring plate was in place, but was battered down vertically, and two of the bolts were sheared vertically. All of the other centring plates were gone and their bolts sheared, those at the south-west being sheared vertically and those at the north-east being sheared 45 deg. down, as were those of the south-east centring plate, which remained free on the girder. The west hoisting link was bent on the south side, and in the east hoisting link the south-west corner was scored and the bottom plate was bent and scored on the south side; while at the north side of the links the corner was bevelled 45 deg. and the links above the pin connections were slightly bent.

At North-West Corner.—At the north-west corner the lower pin was in position and scored, but had not rotated; the west suspension bridle was torn away, but its hitch angles were intact, the east bridle was torn away and its hitch angles bent toward the west; the south-west centring plate was displaced, but remained on the girder with its bolts sheared horizontally, while both the north-west and north-east centring plates were in position with

* Photographs showing the condition of the four corner supports after the accident are reproduced in Figs. 4 to 7 on page 364 *ante*. A larger-scale photograph of the south-eastern corner is also reproduced in Fig. 4 on page 442 of our last issue.

their bolts and were untouched. The bracket and tie plate on the east hoisting link were bent and torn, and the links were bent in toward the centre of the girder.

At North-East Corner.—At the north-east corner the lower pin was in place, rotated 1 in. to the west and uninjured; both of the north centring plates and their bolts were in place and untouched, and both of the south centring plates were gone, their bolts being sheared horizontally. Both girder suspension bridles were gone, but the connection angles were untouched. The top flange of the girder was bent down near the middle, the tie plate for the west hoisting link was bent and torn, and the east face of the link scratched and scored. The north tie plate of the east hoisting link was slightly bent.

At South-East Corner.—At the south-east corner the lower pin was gone, and the upper pin had turned 90 deg. and dropped into the bottom pin bearing in the lower casting. All four centring plates were in place, but bent outwards, and pin grease was found on the upper surfaces of the east centring plates. The east suspension bridle was torn off, but its connection angles were untouched, and the west suspension bridle was battered down and the vertical legs of its connection angles were crushed and bent. The top flange cover plate of the girder was scored on the north side just west of the connection angles and bent down, the marks making an angle of 20 deg. with the bridge axis. At the west hoisting links the connection pin was moved 1 in. up-stream and the nut broken off from its bolt. The hanger rivets were crushed into the links on the west side. The edge of the hanger plate was crushed on the east side and the lower east edge of the brackets slightly bent inward. There was no injury to the east hoisting link.

Since the accident accurate measurements have been made of the hoisting links at the south ends of the bridge, and the south-west corner, where the initial fall took place. These links show a permanent elongation of from $\frac{1}{16}$ to $\frac{1}{8}$ in. in each unit, which is about 30 ft. long, and at the south-east corner, which was the second point to let go, these links showed permanent elongation of $\frac{3}{4}$ to $\frac{5}{8}$ in. in 30 ft. These permanent elongations, of course, show that the links were stretched beyond their elastic limit by the punishment received during the fall. Under the lifting conditions, the stress per square inch in these links, on net section, through pin holes, was 17,000 lb., and as the elastic limit at these sections was in the neighbourhood of 30,000 lb., it shows that the links, rocker castings, &c., received an overload of from 60 to 100 per cent., and even under overload the evidence is conclusive that the rockers at the south-east, north-east and north-west corners did not fail.

In regard to any question of unstable equilibrium at the lifting girders, and apart from any figures, the question of stability is conclusively proven by the photograph taken during the fall, which shows one corner of the bridge probably 60 ft. in the water, and the three other corners still seated on the lifting girders.

Conclusions.—An analysis of the facts and conditions after the accident thoroughly convinced all the engineers that the intermediate or rocker casting at the south-west corner of the span broke and allowed this corner to descend on the lifting girder, moving toward the north-east and slipping entirely off the girder. The south end of the west truss then dropped about 70 ft. lower than the north end, transferring a large part of its load to the east truss through the transverse braces and portals, which successively crippled from west to east, and pulled the south end of the east truss toward the west, twisting and warping the truss and seriously injuring the top chord near the north end, where it is shown by the photograph to be out of alignment.

At this time the principal support of the span was at the south-east and north-west corners. The south end of the span then rotated westward about the south-east corner. The truss tilted on the lower south-east bearing pin, then slipped on the upper or transverse pin, forcing the casting eastward, after which the end post of the bridge slipped off from the bearing, striking the inside face of the west hoisting link, and fell into the river, almost clearing the hoisting girder. Then the north end of the bridge pulled south off from the east and west lifting girders at about the same instant and parallel to the axis of the bridge; the hoisting links swung violently back and forth, and the span plunged to the bottom of the river.

The evidence shows that none of the steel bearing castings was broken, except the intermediate casting of the south-west corner, although during the progressive action of the accident they were subjected to very great stress, which they successfully resisted, thus establishing the excellence of material and of the design for all of them.

Statements to the effect that the bridge was supported in unstable equilibrium during the hoisting, because the hoisting girders were suspended from the hoisting links at a point considerably below the bearings of the span and thus incited rocking and kicking, are entirely erroneous. The connections of the hoisting girders to the hoisting links were above the rocker bearings of the span, and provided a moment of stability.

The statements to the effect that the top chord of the west truss was broken at the second panel point from the south end, that the top chord of the west truss crumpled at the north end, and that the eye-bars in the bottom chord of the east truss were pulled apart at the north end, do not appear to be substantiated.

No evidence has yet been presented that in any way reflects on the character of the design, the strength of the permanent structure, the excellence of materials or workmanship, the method and plan of erection, or the experience, skill, ability and fidelity of the engineers and contractors. The work was of the highest class, most ably executed and conducted, and no time, pains, or money were spared to secure the utmost safety.

The bridge was designed and is being constructed for the Dominion Government under the direction of the Quebec Bridge Commission, consisting of C. M. Monsarrat (chairman and chief engineer), Ralph Modjeski and H. P. Borden. The St. Lawrence Bridge Company, Limited, is the contractor; Phelps Johnson being president; G. H. Duggan, chief engineer; W. P. Ladd, superintendent of manufacture; George F. Porter, engineer of construction; S. P. Mitchell, consulting engineer of erection; and W. B. Fortune, superintendent of erection.

REFRACTORY MATERIALS.

The Faraday Society has opened the new session by one of the useful and much appreciated general discussions in which the Society excels. The subject, "Refractory Materials," is one which equally concerns the engineer, the metallurgist, the chemist, all interested in keramics, and the general public. The meeting was held in the lecture hall of the Institution of Electrical Engineers on Wednesday afternoon and evening. The proceedings were opened at 5.30 and resumed after an interval at 8.30; long meetings are the rule of the Faraday Society, and the meeting was closed at 11.20 p.m. There were 10 papers on the agenda, and quite that number of representatives of diverse scientific and industrial branches took part in the discussions. That the title might have been "Refractories and the War" need hardly be pointed out. The keynote of the discussion was once more the need of co-ordination and co-operation of research to be conducted in the laboratories and in works with due understanding of the aims, needs and limitations of both the sides. The rich collection of exhibits of raw materials, refractory products and specimens from laboratories and works was of quite unusual interest. The exhibition was kept open on the following morning.

In his introductory remarks, which touched upon many points, the President, Sir Robert Hadfield, F.R.S., pointed out that, although the correct kind of refractories was of importance for the satisfactory working of steel furnaces and metallurgical operations generally, the subject had not altogether received in this country the attention it deserved. There were about 200 makers in Great Britain—140 in England, 40 in Scotland, 30 in Wales—notably in Stourbridge, the Sheffield district, Scotland (Eglinton and other places) and South Wales. Lecturing on "Refractory Materials and the War," before the Society of Arts, in January, 1915, Dr. A. B. Searle had stated that the manufacture of chemical porcelain was almost unknown in Great Britain, and that the British firebricks did not satisfy the tests of Continental coke-oven builders. The work done since by Professor Henry Jackson and others in the London and Sheffield Universities had altered conditions, however, Sir Robert remarked. Refractories had largely been imported, though our own country possessed equally good, if not better, material; his own firm could plead guilty to having purchased material from abroad which was really near at hand. The first large-scale development of the Bessemer process had taken place in Sheffield because the Sheffield ganister (95 per cent. of silica, 2 of alumina, 1 of lime, &c.) had proved a particularly good lining material for the converters, as it had been recognised—and was still unsurpassed—as the best lining for the pot-holes in which Sheffield crucible steel was made. Quoting at some length from the "Standard Specifications for Refractory Materials" drawn up on behalf of the Institution of Gas Engineers in 1912 by Dr. H. G. Colman, of London, and Dr. J. W. Mellor, principal of the Staffordshire County Pottery Laboratory, and from a paper read before the same Institution by Mr. F. J. Bywater (now on active service), Sir Robert stated that according to the researches of Bischof, Richters, Seger and others, pure silica had a melting-point of 3,326 deg. F., pure clay a slightly higher melting-point, and that of mixtures of the two materials the mixture $SiO_2,2Al_2O_3$ was the most refractory. The position of a clay in the scale of refractoriness, however, also depended upon the amount of flux present, iron oxide, lime, magnesia, potash, soda; these fluxes seemed to act in the ratio of their equivalents, *i.e.*, 20 parts of MgO had the same effect as 28 parts of CaO, the ratio of the combining weights being $40 : 56 = 20 : 28$. Thus the ultimate analysis of a refractory was often of little use, unless preceded by mechanical or other methods of subdividing the material into its mineralogical constituents, and furnace tests should be applied to mixtures. The Armstrong Cork and Insulating Company, of Pittsburg, was using a ready test by letting a very hot flame (Bunsen burner) play upon the surface of a brick, which was held in the hand until it became too hot; we should think that a man performing this test often would finally pass almost any of these diatomaceous bricks, for which remarkable heat insulation is claimed.

Sir R. Hadfield then passed to other refractories, especially to zirconia, quoting from S. I. Levy's book on "The Rare Earths," Riecke, Conrad Meyer, Percy's "Metallurgy," Kohn on "Moulding Sands," Roberts-Austen's "Introduction to the Study of Metallurgy," and other authorities. As a metallurgist, Sir Robert distinguished acid refractories (dinas rock, ganister, fireclays), basic (dolomite, magnesite), and neutral refractories (bauxite, chrome, iron ore, graphite and a few fireclays). The success of an acid or basic steel process depended upon the acid or basic lining; neutral linings possessed great advantages, but were generally very expensive and difficult to apply; electric furnaces might be given acid linings, but basic, neutral or zirconia linings yielded much better results. For Sheffield crucible steel there was still only choice of two materials: pot clay, a mixture of fireclay, China clay, a little carbon and sometimes small quantities of special materials, the usual mixture being two-thirds raw clay and one-third burnt clay; and plumbago crucibles, fireclay and plumbago suitably mixed. The objection to this latter material was that carbonisation of the melting steel took place, whilst the ordinary Sheffield crucible, used since the days of Huntsman, gave a uniform steel; that was the open secret of the uniformity of Sheffield crucible steel. Howe had also used blocks of millstone grit from the Sheffield moors, with fair results.

With regard to his own exhibits, Sir Robert remarked that sand for open-hearth bottoms had almost entirely been supplied by Belgium, but some British sand, first used mixed with Belgian sand after the outbreak of the war, gave practically the same results. "Half-baked" silica bricks often caused serious troubles. Fireclay nozzles were attacked by manganese steel, which did not attack

magnesite nozzles; the latter were more used now. The nozzles exhibited to illustrate this superiority of magnesite nozzles, which was pointed out for the first time, were most striking. Sir Robert had tried a combination of fireclay and magnesite for nozzles, but it had not answered. Fireclay nozzles wore badly; fireclay stoppers in magnesite nozzles were apt to collapse during casting; magnesite stoppers, so far, were not a success, as they were liable to crack and spelch. Plumbago nozzles and stoppers had not proved any better in his experiments than fireclay products. Dolomite bricks would be invaluable for the roof and walls of electric furnaces if means could be devised to prevent perishing. The literature list with which Sir Robert concluded his paper also contained a large number of analyses made in his works.

Dr. J. W. Mellor, of Stoke-on-Trent, followed with a paper on "The Texture of Firebricks," which was one of the most important questions to be considered, he stated, since the life and character of a firebrick were largely determined by its texture. The texture varied from the porous texture of bricks for boiler insulation to that of the non-porous and vitreous materials for crucibles and acid-resisting bricks. In the specimens which Dr. Mellor exhibited the bricks had been cut transversely, and the exposed surface had been polished and photographed; a glass plate had then been cemented to the polished face (by means of Canada balsam); the method was due to Mr. Lomax; the specimens illustrated a great variety of British (and also German) bricks and experimental results. The more important mineral constituents of clays, Dr. Mellor continued, were the granular feldspathic or micaceous fluxes, granules of clay proper, and quartz grains. Virtually, Nature might be said to have made all fireclays by mixing these three components with accidental and often deleterious impurities—schorl, pyrites, siderite, &c. The osmose process of clay purification removed these impurities, but slipping and lawning the weathered clay should first be applied; either process improved the clay, but ran up the cost, of course. In the kilns the fluxes begun to melt at 900 or 1,000 deg. C. and to attack the grains of quartz and dry clay at higher temperatures clay and quartz reacted on one another, and either might be considered the flux. The fluxing action was necessary to bind the brick to a compact whole of mechanical strength able to withstand also abrasion and attack by flue dust, slags, &c.; the fluxing was a time action and long heating at low temperature would, apart from secondary effects, produce the same contraction as short heating at high temperature.

When the size of grain was reduced, the number of grains increased enormously. If a clay contained 720 grains of 1 mm. diameter per gramme, there would be 720,000,000,000,000 grains of 0.0001 mm. On the same reduction of size the surface area would increase from 22.6 to 226,415 sq. cm. The grains were not spherical, of course, nor regular, but angular, and that was desirable; round quartz grains were not firmly embedded in the matrix. Pressure lowered the softening temperature; according to recent experiments by Drs. Mellor and B. J. Moore the squatting temperature was given by $Ce=kP$, where C was the squatting temperature of the clay under no load, P the load in lb. per square centimetre, e the logarithmic base, and k a constant of the order of 0.001, generally much smaller for siliceous than for aluminous clays, however. As anything favouring vitrification would reduce the refractoriness, the coarser grain and texture would be less liable to soften. This was very noticeable with fluxes of clay and fine-grained silica, which spoiled a brick, whilst coarse-grained silica improved the refractoriness. With gradual heating the surfaces of the more fusible granules melted first, and for that reason again refractory bricks should be coarse-grained.

Proceeding, Dr. Mellor said that he had called the changes occurring during the firing of a refractory *arrested reactions*. The fluxes melted, and dissolved and bound the other material, and there was a certain amount of contraction which, if not completed, went on afterwards in the used brick. A few years ago that *after-contraction*, for which bricks were tested to specification, had amounted to 2 or 3 per cent.; now it was reduced to 1 or ½ per cent., but it was usually impracticable to suppress it altogether, even if the bricks were fired a dozen times. With silica bricks there was generally an *after-expansion*, due to the change of quartzose silica (density 2.65) to a lighter silica (2.3). Quartzose also occurred in clays, and fluxes also expanded during firing by 6 per cent.; whilst clay contracted by 4 per cent., increasing its density from 2.6 to 2.7. The normal contraction (or expansion) was thus a joint effect, but contraction predominated. Siliceous material might be, and had been, added to balance the volume changes; as long as the silica were coarse-grained and suitable, and the firing was proper, Dr. Mellor saw no harm in this practice, which had been condemned as fraudulent.

"Grog" was burnt fireclay or ground firebrick added to the fireclay to serve as a skeleton. If the grog were of the same material, the main difference between the grog and the other clay was that the former had been fired twice and the latter once. That difference tended to vanish with subsequent firings; but if the grog had been fired at higher temperatures, or been made of old materials, the life history of a grog could be followed through 40 firings. Great care should be exercised in the grading of the grog and the fireclay; they should not be mixed in any machine which had a grinding action. The refractoriness could be increased by adding shrunk bauxite, zirconia, carborundum, &c.; the addition of these higher refractories had strong and weak points, because refractoriness should not be pushed at the expense of other properties. Coarse-grained textures were little liable to crack on sudden temperature changes (Edwards and Leese, 1902), it was true; but the crushing strength and tenacity were low, and the coarse grains were more easily penetrated by slags.

As regards machine-made *versus* hand-made firebricks, badly made machine bricks were worse than bad hand-made bricks. But the prejudice against the former was partly due to unfair comparison; it was rather the shorter time the clay was allowed to weather and to turn plastic than the machine process which deteriorated the machine product. Pug-mills, moreover, were not good mixers; some of the specimens exhibited showed lamination, which favoured cracking and probably spalling. Uniformity of mixture was very essential; in dry or semi-dry machine-mixing air films got between the granules.

A satisfactory substitute for the determination of refractoriness was not yet known; chemical analysis could not supply it. The analyst should clearly distinguish between fine-grained fireclays, coarse-grained fireclays, and firebricks. Analysis was needed, of course, also for checking the mixing and blending. In a composite brick (fortified with quartz, bauxite, &c.) the consumer should be told the approximate proportion and character of the binding clay and the fortifying agent. "Trade secrets prevail most in works whose future lies behind them."

Referring to coarse-grained firebricks in particular, Dr. Mellor said that the above-stated rule, that the coarse grain stood sudden temperature changes best, was not without exception in both senses. Magnesia was also unreliable in this respect. Silica bricks were particularly liable to crack, no matter of what grain; in the first fire the fluxing became saturated with silica, the mixture set, and when the set of the grains was afterwards disturbed by internal expansion the binding agent was weakened. Pre-calcination at a high temperature of the silica might mitigate the trouble; this was done; such bricks did not "ring" so clearly when struck together, however. Other things being equal, fine-grained bricks resisted abrasion, fluxes, flue dust, slags, salt vapours, &c., but, of course, acidic bricks were corroded by basic fluxes and *vice versa*. Weak spots were developed by slags into 'salients'; the joints between the bricks were the weakest spots, and ultimately a brick left the setting and floated on the slag. Large slabs, on the other hand, were liable to crack, and where slag attacks were feared, bricks of uniform size, close texture and small joints should be used. When bricks with open and bricks with close texture were exposed to salt vapours, the latter seemed to be more attacked, becoming covered with a thin film of glaze; but the vapours really penetrated more deeply into the open texture, and that became apparent after a longer time.

Concluding, Dr. Mellor said that the manufacturer could largely control the texture, and the consumer should consider the conditions in the different parts of the furnace. Near the top, temperatures were not very high, but fluctuated much, and abrasion by impact had to be guarded against; there was also disintegration because the carbon deposited and the gases reacted with the iron oxide in the bricks, especially when there were oxide nodules; the bricks should be close, compact and tough. In the mid zone slags and salt fluxes had their play, and temperatures were high. In the hearth and bosh the scouring action was severe; the volume changes in the bricks should be small, but tear and abrasion was not likely. Stove-bricks should have a high thermal capacity, and be able to resist sand-blast effects; as regards the heat capacity, the remarkable rise in the specific heat of firebricks with higher temperature was noteworthy. The specific heat the manufacturer might not be able to control; but he could make the bricks strong against streams of fine dust and chemically resistant.

Dr. H. G. Colman, of London, briefly reviewed the work of "The Joint Refractory Materials Committee of the Institution of Gas Engineers and of the Society of British Gas Industries." The committee, he stated, had been appointed in 1908, when Mr. F. J. Bywater, now Lieut.-Colonel on active service, had brought the question of refractory materials before the former body. Dr. Colman was chairman; the main work, he said, had been done by Mr. Bywater and Dr. Mellor. Their task had been to draw up standard specifications and to conduct research. For the first purpose they had visited a number of typical gas works to determine the actual needs, temperature fluctuations, &c. They had not attempted to lay down any ideal rules, but to fix something likely to be complied with. The specifications dealt with three materials: retort or ordinary firebricks, blocks of less than 80 per cent. silica, silica bricks with more than 90 per cent. of SiO_2. The retort material presented special difficulties because of the rapid and large temperature fluctuations, the hot retorts being refilled with cold coal. The specifications required that the fine dust should be removed from the grog in the manufacture of retorts; at the same time an open, porous structure was required. Those difficulties were not the worst, however; great mechanical strength was required for the retorts, and in that respect also considerable improvement had been realised. As regards research, they had not had any suitable laboratory of their own, but they had had the co-operation of the Stoke-on-Trent Education Committee and lately a grant from the Privy Council. With all this, however, their means amounted to 230*l.* annually only. One of the chief subjects studied was the influence of pressure on refractories. The material of a retort setting was generally under pressure and in contact with a reducing material and reducing gases, whilst the ordinary specification tests were performed in an oxidising atmosphere under no load; they quite understood that this was not desirable, but no satisfactory method of conducting the tests under actual retort conditions had yet been worked out. Both the load and the reducing effects tended to lower the refractoriness, as Dr. Mellor had pointed out. A great many other subjects were under investigation, especially also the important volume changes in the hot and cold materials.

Dr. R. Lessing, of London, showed a very instructive series of specimens illustrating a method of testing he devised five or six years ago for ascertaining the texture and rational composition of refractory mixtures before firing. It consists of a simple process of elutriation by which the true clay substance of the "green" clay is removed by a gentle current of water and separated from the water by allowing it to settle out on standing. The rate of flow of water is so adjusted that the "grog," and also the heavy and coarse grain residue of the "green" clay, consisting of sand, shale, or carbonaceous substances, are left behind in the elutriating vessel. A very simple form of elutriator, accurate enough for works purposes, consisted of a tall glass cylinder into which the water was passed through a glass tube reaching nearly to the bottom. The

cylinder was placed in a bucket into which the clay suspension overflowed, and from which the clear water was siphoned off after settling. For the purpose of the test about 500 grams of the sample (which might be taken before or after "tempering," or from a moulded body before or after drying) were well soaked in water and washed into the cylinder. The resultant products of clay and residue were dried, and a grading test was then performed on the residue, from which the texture of the body and the ratio of "grog," granular clay, shale and coal could be ascertained.

The specimens exhibited showed that, before the standard specification was adopted, mixtures for gas retorts contained very little grog, which had, moreover, suffered from excessive crushing yielding dust, whilst the "green" clay serving as binder had largely remained in the form of coarse granules instead of being reduced to fine powder. The change in manufacturing methods by which the grog was crushed and graded separately and the powdered "green" clay mixed with it, were shown by specimens taken after the adoption of the standard specification. For comparison, a sample of a German retort mixture was shown, which was remarkable for its large proportion of grog, viz., 66 per cent., as against about 35 per cent. in English retorts, and also for the total absence of clay residue, shale, or coal, indicating that the binding clay had undergone some preliminary purification.

The test has been used successfully for the daily control of manufacturing operations, and was recommended by the author for this purpose, and was, in the absence of a reliable quantitative method for ascertaining the texture and rational composition of refractories, a simple and useful guide. It is only applicable to non-fired materials.

Mr. Albert Cliff, of Stamford, contributed a short paper on "The Manufacture of Refractory Materials." He stated that it was his function to say a few things from the maker's point of view. Unfortunately, he spoke with the full reticence of the manufacturer; he regretted that men of science did not communicate more freely facts and principles to the youths of the fireclay districts, but he offered very little information himself, contenting himself with emphasising the need of improved education. British manufacturers, he said, had restricted themselves almost wholly to the output of retorts, blocks, and bricks in fireclay or silica. As regards gas retorts there was still cleavage of opinion concerning hand-made and machine-made retorts; old material that had done service for years should be returned to the seat of manufacture; discoloration by carbon did not matter, partially fused or slagged pieces should be kept out. Makers had so far mostly concerned themselves with acid refractories; but there was much promise in basic and neutral groups, and in the present difficult conditions they were endeavouring to fasten working surfaces of chromite, magnesite, or other materials on ordinary fire or silica bricks, a variation of the approved facing of bricks. Mr. Cliff exhibited samples which he considered encouraging, without giving particulars.

Mr. W. Donald, of Glasgow, being unable to attend, communicated some suggestions as to the exhibits by the Eglinton Silica Brick Company of magnesite (raw and calcined) from Greece and magnesite bricks. These bricks had chiefly been made in Austria before the war, and when the firm had experimented they had found that the magnesite was too pure, but could be improved by adding iron oxide (8 per cent of Fe_2O_3) to secure binding strength without reducing the refractoriness. They were mainly interested now in linings for basic steel furnaces. America used a magnesite cement for this purpose, rather than dolomite. Over here magnesite bricks were used and lined with 14 in. of dolomite, carefully rammed and fitted in, in layers of 3 in. This rammed dolomite, however, boiled with the steel, not, Mr. Douglas thought, because the dolomite was bad, but because ferrates of lime were formed (dolomite is the natural double carbonate of magnesia and lime), and the magnesite underneath was destroyed. As the Americans did not mention this point, ferrates of magnesia might not be formed under furnace conditions. With the use of dolomite there was also constant need of fettling and hence loss of heat, but the methods in use in America should be tried here. So far magnesite cement had not answered well. When the metal was poured into the steel furnace from the blast-furnace, the magnesite would not bear the weight of the metal any better than the dolomite did, and it was even more difficult to fettle. Mr. Douglas also referred to the exhibits of chrome (ore, cement, brick), and to the suggestions they had made to the Iron and Steel Institute that standards for refractories should be set up.

(To be continued.)

NOTE.

The Marine Diesel Engine.

In a paper recently read before the Institute of Marine Engineers Mr. J. D. McArthur points out that the Diesel engine cannot meet present-day requirements for power to more than a very limited extent. In normal years over 20,000,000 tons of British coal are supplied for bunker purposes, and at least 4,000,000 tons of oil would be required were the whole of our shipping fitted with Diesel engines. This quantity could not be supplied from the oilfields at any reasonable price, if at all, whilst if the oil required were obtained from coal it would be necessary to extract an average of 2 gallons of Diesel oil from every ton of coal brought to bank in the kingdom. If internal combustion engines are to be used for ship propulsion, Mr. McArthur suggests that the gas engine provides a more practicable solution of the problem than does the Diesel engine, since the supply of suitable fuel need then create no difficulty, particularly if, as seems probable, there will in the future be a very great increase in the output of suitable coke. The saving in weight due to the replacement of the ordinary marine boiler by producers he estimates at 40 per cent. in the case of small plants and more with larger. A producer rated at 100 brake horse-power requires, he says, a grate area of but 3 sq. ft. when anthracite is the fuel used, 3.5 sq. ft. for coke, and 4.5 sq. ft. with bituminous coal, as against the 10–12 sq. ft. required in ordinary marine boilers. As coke costs not more than four-elevenths of the price of fuel oil the higher efficiency of the Diesel engine, as compared with the combined efficiency of the gas engine and producer, is rapidly discounted. The gas engine further has the advantage of more moderate cylinder pressures, permitting the use of ordinary good iron castings for the cylinders, valves, and covers. Hence Mr. McArthur concludes, that the Diesel engine can never be of prime importance for marine propulsion, appealing principally, as it does, to shipowners of foreign countries devoid of coalfields, or to British owners regularly trading to oil-producing centres.

The Cement Industry of Japan.—The cement industry of Japan, which was at a low ebb for a long time after 1911, owing to the reduced demand and the increased output, experienced a marked improvement last year, which has developed during 1916, says *The London and China Telegraph*. Present prices are about double those ruling at the beginning of the year, as a result of great activity of the export market and the increased domestic demand. Exports have gone up steadily from 67,651 barrels, worth 32,700*l.*, in 1911, to 668,613 barrels, worth 245,800*l.* last year. It is expected that the current year's exports will reach 1,000,000 barrels. The increase in the foreign demand is attributed to the conditions produced by the war. Stocks of European cement in Oriental and other markets have been exhausted. There are 16 cement companies in Japan, and they have 20 factories.

Our Coal Abroad.—Our export coal trade is being more and more contracted, high prices and transport difficulties exerting a decidedly adverse influence The exports of coal from the United Kingdom in September were 3,414,180 tons, as compared with 3,892,033 tons in September, 1915, and 3,859,188 tons in September, 1914. These totals were increased by the addition of coke and patent fuel to 3,698,566 tons, 4,096,637 tons, and 4,096,453 tons respectively. Coal was also shipped to the extent of 1,062,707 tons, 1,064,967 tons, and 1,332,935 tons respectively for the use of steamers engaged in foreign trade. In the nine months ending September 30 this year our aggregate coal exports were 29,243,377 tons, as compared with 33,414,212 tons in the first three quarters of 1915 and 48,116,349 tons in the first three quarters of 1914. These totals were increased by the addition of coke and patent fuel to 31,442,872 tons, 35,059,537 tons, and 50,372,612 tons respectively. The aggregate shipments of bunker coal—that is, coal shipped for the use of steamers engaged in foreign trade—to September 30 this year were 9,820,906 tons, as compared with 10,722,894 tons and 14,581,962 tons.

FOREIGN ENGINEERING PROJECTS.

We give below a few data on several foreign engineering projects, taken from the *Board of Trade Journal*. Further information on these projects can be obtained from the Commercial Intelligence Branch, Board of Trade, 73, Basinghall-street, E.C.

Brazil.—The *Diaro Official*, Rio de Janeiro, publishes a Decree (No. 12,185) conceding to Sr. Alberto Alvares de Azevedo de Castro permission to construct and work a railway from Cuyabá, the capital of the State of Matto Grosso, *via* Sant'Anna do Paranahyba, to the Araraquara Railway, with which it will connect either at Jangada or at S. José do Rio Preto. The line will be single track and of metre gauge. Plans relating to sections of not less than 100 km. (about 62 miles) must be submitted for the approval of the Government. Those for the first section must be presented not later than June 30, 1919, and those for all the other sections must be presented by the end of 1924. Construction work must be commenced within a period of a year from the date of the approval of the plans relative to the first section, and at least 50 km. (31 miles) of line must be constructed each year. The concession is for a period of 60 years, counting from January 1, 1920.

Spain.—The *Gaceta de Madrid* publishes a notice, issued by the "Ministerio de Fomento," authorising the "Sociedad Electro Metalúrgica del Ebro" to utilise the waters of the River Ebro, in the district of Sástago, at the rate of 120 cub. m. per second, for industrial purposes. The necessary works must be commenced within a period of three months from the date of granting the concession, and must be completed within five years.

Dutch Shipping.—The report of the Amsterdam Chamber of Commerce for last year draws attention to the fact that, although the tonnage of the Dutch mercantile navy remained almost stationary during 1915, Dutch ship-owners were bent upon increasing its capacity, inasmuch as, at the end of last year, there were in course of building for Dutch account 128 steamers, with an aggregate of 410,000 tons, an increase in tonnage of more than 50 per cent.; with the exception of 4 being built in America, these vessels were all being built at home yards.

Norwegian Shipping Contracts.—A meeting was held in Christiania, the Prime Minister in the chair, on October 20 to discuss what steps could be taken to put a stop to the excessive building of ships abroad for Norwegian account, and it was stated that the aggregate price of vessels ordered abroad by Norwegian owners in all likelihood amounted to some 600,000,000 kroner. It was decided to recommend the Government to urge Norwegian banks to assist at no further contracting of tonnage at foreign yards for Norwegian account, and this the Government has now done, after further deliberation, in a communication to the Bank of Norway.

Steel in Germany.—The production of steel in Germany is steadily increasing, and the figures for the first nine months of the current and the two preceding years were as under:—1914, 12,225,000 tons; 1915, 9,673,000 tons; 1916, 11,930,000 tons. The production per day during September was the next best since the commencement of the war, viz., 53,594 tons, against 54,971 tons for June, 1916. So far, the production of steel during 1916 exceeds by 25 per cent. that of the previous year, and is only 3 per cent. short of that of the same period of 1914, although out of the nine months in question of that year seven months were prior to the commencement of the war. At the last meeting of the Steel Union it was announced that within the shaped iron branch the demand for military purposes had increased, so that very little remained available for ordinary trade. The active demand from neutral countries continued, but could only be satisfied to a very limited extent. The demand for half-finished products was very lively, and within this section all export had been stopped. Also in railway material the sale to neutral countries has almost come to a standstill on account of the strong home demand.

The German Navy.—The Italian *Rivista Marittima* states that the German Navy at the present time consists of 27 Dreadnoughts, including the battle-cruisers, 19 pre-Dreadnoughts, without counting the small cruisers of the "Hagens" class, 3 armoured cruisers, 32 to 34 light cruisers, 148 destroyers, 65 torpedo boats, and a problematic number of submarines. According to recent information, it would appear that the additions to the German naval forces include a certain number of monitors and a few warships which had been formerly struck out from the list and have been rendered invulnerable to submarine explosions. The monitors are for service against the Russian mobile defences and batteries. The Germans use their old cruisers to convoy merchant steamers in the Baltic. It is stated that the battleship Ersatz Wörth is very similar to the Queen Elizabeth. According to semi-official Austrian information, the Ersatz Wörth has a length of 190 m. (623 ft.) and her speed would be nearer 25 knots than the 21.5 knots which is generally ascribed to her. The battleship "T." (budget of 1913), the Ersatz Wörth (budget of 1913) and the Ersatz Kaiser Friedrich III (budget of 1914), in construction when war broke out, belong to one and the same class; according to some, one of the first two of these units has received the name of Bayern.

PROGRESS AND POSITION OF THE SHIPBUILDING TRADE.

Lloyd's Register of Shipping occupies such a unique position as regards the mercantile marine of the world that their Annual Reports are more or less an epitome of the history of shipbuilding. This year's record, for the period ended with June last, issued this week, forms no exception to the rule. It is brought out that at the present time there is building, under the inspection of Lloyd's, a larger amount of tonnage than has ever been recorded in the history of the Society, namely, 620 vessels of 2,282,709 tons. This testimony to the world-wide acceptance of Lloyd's is a guarantee of efficiency, alike in regard to design and construction. This total, it may be said, is about 10 per cent. of the tonnage classified in the Register Book of the Society at June last, when there were 10,032 vessels of 23,190,138 tons included. Notwithstanding the ravages of war, the British tonnage was 13,563,177 tons, while the total of all other countries' ships was 9,626,961 tons. Again, as regards the vessels assigned or classed during the year, 52½ per cent. were built for the British Empire and 47½ per cent. for other countries. The total, however, was only 790,209 tons, which is far below the average, a direct consequence of the demands made by belligerent countries for war supplies.

It is pointed out that in neutral countries, and particularly in the United States of America, every effort has been and is being made, by means of the extension of existing plants and the creation of new establishments, to cope with the increasing demand for tonnage; and it is notable that, largely as the result of the visit of Mr. Andrew Scott, the secretary to Lloyd's, to America, an American committee has been formed, composed of the leading underwriters, shipowners, shipbuilders and engineers, to co-operate with the officials of Lloyd's Register in meeting still more fully in the future even than in the past the requirements of the American maritime trade. The American staff, too, has been reorganised, so that Lloyd's Register is destined to be still more closely allied with the shipping industry of the United States. The Government of the United States of America, too, have recently invited 40 of the leading American shipbuilders and ship-owning companies to attend a conference at Washington for the purpose of exchanging views on the subjects of load line and bulkheads and other phases of the construction of steamers on the ocean and the great lakes.

As regards the features of the work completed, it is pointed out that 32 vessels of 156,975 tons were built last year under the Isherwood system of longitudinal framing. This brings the total to over 2,500,000 tons. For carrying oil in bulk 14 vessels of 77,167 tons were built, bringing the total up to 1,380,235 tons. Vessels fitted for burning oil fuel now number 269 and measure 1,259,714 tons. Owing to the increased demands made for oil in this country many proposals to supplement the supply by converting ordinary cargo steamers into oil carriers have been dealt with by Lloyd's Committee.

A notable fact is that the past year has witnessed the revival of wood shipbuilding in America, owing to the abnormal demand for steel. Since the beginning of 1916 Lloyd's Committee have considered proposals for the construction of several vessels to be built of wood, ranging from 100 to over 300 ft. in length, the dimensions generally being similar to those of the four, five and six-masted schooners built in the United States, the largest of which are 320 ft. in length and 50 ft. in breadth. Several of these wooden vessels are being built on the Pacific Coast for use in the lumber trade of Australia. The principal wood used is Oregon pine or Douglas fir, found in great abundance on the Pacific slope. Steel reinforcements are introduced in the larger vessels at the keel and gunwale and at the various decks for giving the necessary longitudinal strength to the structure. In addition to the sail power the vessels are fitted with single or twin screw oil engines for auxiliary use when necessary, donkey boilers being supplied for working windlasses and winches. Some of the larger boats will, however, be propelled by steam power alone.

Note is made of the increasing use of geared steam turbines, 9 vessels with such engines having been built to the Society's classification during the past year. At the present time there are 52 vessels in course of construction, with a view to being classed in Lloyd's Register Book, in which geared turbines will be fitted, 25 with Parsons single-geared turbines, and 27 with Curtis double-reduction geared turbines. Two vessels are being built to the Society's classification in which Ljungstrom turbo-electric propelling plant will be fitted, one, a single-screw vessel, in which the power will be 1,500 shaft horse-power, and the second a twin-screw vessel with a total shaft horse-power of 5,400. Regarding this installation, Lloyd's Committee state in their report:—"In the Ljungstrom turbine there are no stationary blades, the steam passes across two sets of blades which revolve at equal speed in opposite directions, so that the effect is similar to that which would occur with one set of blades stationary and the other set moving at twice the velocity. Each half of the turbine is directly coupled to its own alternator, producing a three-phase current of about 50 alternations per second, with a voltage of about 800. The two alternators are electrically locked, ensuring exactly equal speed, and consequently equal power, on each rotating half of the turbine. In each vessel there will be two turbo-alternator sets, so that the stoppage of one will not disable the vessel. The two alternators of each set work in parallel. They have each only one pair of poles. They supply current to two motors, each having five pairs of poles, which will therefore rotate at one-fifth the speed of the turbines. These motors are connected to pinions with spiral teeth which gear in the ordinary manner with a large gear wheel secured to the screw shaft. The combination of electrical and mechanical reduction gear will enable a turbine running at 3,600 revolutions per minute to rotate the screw at 76 revolutions per minute. The reversing of the screw is effected by the electrical motor, the steam turbines always running in one direction. Reduction of speed is effected down to about 80 per cent. of the full speed by varying the steam supply to the turbine. For slower speeds the regulation is effected by interposing resistances in the circuit."

Seven vessels with Diesel engines were classified during the year, 3 built by Messrs. Harland and Wolff, Limited, and engined by Messrs. Burmeister and Wain, of Glasgow, and the remaining 4 by Messrs. Burmeister and Wain, of Copenhagen. There are now 46 vessels holding Lloyd's classification fitted with engines of this type, and there are at present in course of construction over 30 sets of these engines. Twelve of the 46 vessels are equipped with "Werkspoor" four-cycle Diesel engines. In addition to the foregoing, several vessels have been fitted with oil engines of other than the Diesel type, among which may be mentioned 11 fitted with hot-bulb engines made by Messrs. J. and C. G. Bolinder's Mekaniske Verkstads Aktiebolag, of Stockholm, and this type of engine is to be fitted in more than 30 vessels which are being built under Lloyd's inspection. An interesting announcement has been made to the effect that an Association has been formed by the British marine oil engine manufacturers "for the promotion of the industry by the mutual interchange of experience, for standardising designs as far as practicable, and for carrying out such investigations and research work as may be necessary for the proper development of this type of machinery." This Association was the direct outcome of the discussion at the last spring meeting of the Institution of Naval Architects, when such a proposal was strongly urged upon engine manufacturers by Mr. J. T. Milton, chief engineer-surveyor of Lloyd's. We believe that the Association is very strongly supported, and has already got to work, with every promise of valuable results, not only in the co-ordination of data already evolved but in the development of new research work in several directions. Mr. Milton is chairman during the initiatory stages, having been elected an honorary member of the Association.

Other phases of Lloyd's work are represented by the fact that there are now 174 vessels holding the Society's certificate in respect of refrigerating machinery, the total insulated cargo capacity being about 37,500,000 cub. ft. The Society's surveyors have held on these vessels 1,017 surveys at loading and discharging ports during the past 12 months. The work of inspecting the cold stores in various parts of the world is being continued. During the year 976,801 tons of ship and boiler steel were tested by the Society's surveyors. There are 103 steel manufacturing firms in the United Kingdom and 117 abroad recognised by Lloyd's Committee for the production of steel for ship work. The total length of chain cable tested during the year at the public proving houses in the United Kingdom was 649,556 fathoms, and the number of anchors tested was 12,686. In addition to the British proving houses, 9 anchor and chain-cable testing machines on the Continent, 23 in the United States and 2 in Japan are recognised by Lloyd's.

The Wiesbaden or Ersatz Gazelle.—We read in the *Rivista Marittima* that this light cruiser (budget of 1913–14), commenced at the Weser yard, Bremen, in June, 1914, and sunk at the Jutland battle, had the following characteristic features, according to information since received: Displacement, 5,000 tons; length, 145 m. (over 475 ft.); power, 31,000 h.p., of which 6,000 h.p. were on the central shaft, which was driven by Diesel engines, and 12,500 h.p. on each of the wing shafts, which were turbine driven; maximum speed, 27.5 knots; cruising speed with the Diesel engines, 16 knots; radius of action at the economical speed, 15,000 miles; armament, twelve 105 mm. (4.1 in.) guns and two torpedo tubes; the belt armour was 100 mm. (3.9 in.) thick at the water line.

GERMAN WAR PROFITS.

As the reports for the financial year 1915–16 keep appearing, it becomes more and more evident that large sections of German industry are profiting greatly from the war, in some cases even more than one is able fully to ascertain, owing to the manner in which some concerns adopt the principle of still or invisible reserves, or of clubbing war profit tax reserve, together with "other creditors," &c.

The Augsburg–Nürnberg Machine Company, after, for instance, having written 2,500,000 marks off for orders and outstanding amounts in hostile countries, has a surplus of 5,821,008 marks, against 2,802,743 marks for the preceding year, the dividend being fixed at 10 per cent., against 8 per cent. for the previous year, 1,000,000 marks being reserved for aid purposes.

The Witten Cast Steel Company, at Witten, paid a dividend for the last financial year of 27 per cent., against 18 per cent. for the previous year. The Georg–Marie Mining and Iron Works have a working surplus for 1915–16 of 9,965,663 marks, against 6,289,468 marks, for 1914–15; the preference shares receive a dividend of 7 per cent., against 6 per cent. for the previous year, and the ordinary shares 5 per cent., against no dividend for the previous year. The Kappel Machine Company, Chemnitz, pays a dividend of 28 per cent. for 1915–16, against 4 per cent. for 1913–14.

The Gelsenkirchen Cast Steel and Iron Works, which prior to the war paid very modest dividends of from 4 to 6 per cent., have during the two war years paid respectively 12 and 25 per cent. The company is about to increase its capital from 3,500,000 marks to 4,500,000 marks, and the company has acquired the Krieger steel works in Düsseldorf; the company some years ago absorbed the Hagen Steel Works. The Poege Electricity Company, in Chemnitz, paid a dividend of 15 per cent. for last year, against 7½ per cent. for the previous year, and the state of employment in that concern, as in numerous others, is even better at present than a year ago.

The Laura Hütte has net profits for 1915–16 amounting to 5,408,437 marks, against 2,682,688 marks for the previous year, the dividend for last year being fixed at 10 per cent., against 4 per cent. for 1914–15. Both production and sale of coal, rolled iron, &c., showed a material increase compared with the preceding year, although still behind the figures of 1913–14. The Silesian Iron Works have firm orders for the current year amounting to 36,795,100 marks, against some 23,000,000 marks a year ago. Of the Polish iron works of the company the Blackownia works had partly commenced work, but the earnings could not cover the losses on the Katharina Hütte, which was still closed down. A rise of the coal prices was urged, which had hitherto been negatived by the Minister of Commerce.

Canadian Timber.—During the first eight months o the present year the value of the exports of forest products from Canada increased by 18 per cent. as compared with the corresponding period of 1915. When the comparison is extended to 1914, the increase is carried to 25 per cent.

Acetylene Regulations.—The Home Secretary has appointed Major Aston McNeill Cooper Cooper-Key, C.B., His Majesty's Chief Inspector of Explosives (chairman); Engineer Captain Charles W. J. Bearblock, R.N.; Professor Charles Vernon Boys, F.R.S.; Major Thomas Henry Crozier, one of His Majesty's Inspectors of Explosives; William Sydney Smith, Esq., His Majesty's Inspector for Dangerous Trades; and Dr. T. E. Stanton, F.R.S., Superintendent of the Engineering Department of the National Physical Laboratory, to be a committee to consider the existing regulations in regard to cylinders of dissolved acetylene compressed into a porous substance, and to suggest amendments of these regulations where this appears desirable. The secretary to the committee will be Major Crozier, and all communications should be addressed to him at the Home Office.

Public Works Finance.—At the close of March this year the Public Works Loan Commissioners had advanced 12,244,282*l.* to various local bodies. Of this aggregate 10,330,459*l.* had been repaid to the amount of 5,281,379*l.* Loans had been remitted or written off to the extent of 1,913,823*l.* In this latter total work, house loans figured for 1,370,535*l.* The largest advances to the close of March this year were: Bridges and ferries (England), 298,590*l.*; canals and rivers (Scotland), 100,000*l.*; colleges (England), 108,000*l.*; collieries and mines, 303,700*l.*; compensation for damage during riots (England), 80,750*l.*; improvement of cities and towns (England), 772,600*l.*; improvement of cities and towns (Scotland), 147,000*l.*; Public Works Manufacturing Districts Act, 1863–4 (England), 1,759,015*l.*; railways (England), 490,600*l.*; roads (England), 562,300*l.*; roads (Scotland), 103,970*l.*; Thames tunnel, 250,500*l.*; waterworks (England), 137,000*l.*; waterworks (Ireland), 479,000*l.*; and harbours, 587,600*l.* The Board made 842 advances in 1915–16 for sums amounting to 1,864,224*l.* as compared with 1,982 advances for sums amounting to 4,698,602*l.* in 1914–15. Of the 1,864,224*l.*, 1,511,710*l.* was advanced on the security of local rates and 352,514*l.* on the security of property. The average rate of interest on loans granted in 1915–16 was 3*l.* 19*s.* 10*d.* per cent. per annum, as compared with 3*l.* 13*s.* 9*d.* per cent. per annum in 1914–15. Of the loans granted in 1915–16, 554,328*l.* represented advances made under the Housing of the Working Classes Acts, for providing dwellings for munition workers in various centres.

AUTOMATIC HACK-SAW GRINDER.

In the adjacent column we illustrate an automatic hack-saw grinder constructed by the Wardwell Manufacturing Company, of Cleveland, Ohio, and specially designed for re-sharpening power hack-saw blades. The object of it is to avoid the practice of throwing away blunted blades, since by the aid of this machine they can be re-sharpened eight or ten times, the actual cost of each operation being only 1*d*. All hack-saw blades up to 36 in. long, having teeth as fine as 33 to the inch, can be re-sharpened at a speed of 65 teeth per minute. It is, of course, undesirable to wear the blade too far before sharpening.

The operation of the machine is extremely simple. From the main drive shaft, which extends across the back of the machine, a belt transmits power to the shaft which drives the grinding wheel. This shaft is suspended at the end of an arm, the opposite end of which is supported between hardened steel pivots on a segment. This allows the grinding wheel head to be set at such an angle as to allow the edge or corner only of the grinding wheel to come in contact with the face of the tooth, and the opposite edge or corner on the back of the tooth, and by so doing the wheel through its action dresses itself by wear always to a knife edge. Two adjustments control the movements of this head: one governs the depth that the grinding wheel is allowed to go into the gullet of the tooth, the other regulates the amount of cut to be taken from the back of the tooth. This last adjustment (the control of cut from the back of the tooth) is made by the adjustment screw coming in contact at the proper time with a roller which rides on a cam. This single cam controls all the different-shaped backs of teeth.

Where teeth are extremely shallow or deep an adjustment permits of raising or lowering the point of the cam. Power is taken from the main drive shaft, through a worm gear to the shaft at the left-hand side of the machine, on the end of which shaft there is a slotted eccentric with a screw feed. This eccentric governs the movement or feed of the blade to the machine. There is a scale on the eccentric that is so marked that the proper feed adjustment can be quickly made. An adjustment at the right-hand side of the machine permits of a heavy or light cut being taken off from the face of the tooth, depending on the amount the face of the tooth is advanced beyond the edge of the grinding wheel. The proper combination of these adjustments enables the grinding wheel to be so perfectly timed that when the wheel has travelled all the way down the face of the tooth the cam comes into action and raises the wheel as it travels up over the back of the tooth. One-half of 1,000th of an inch can be removed from either the face or back of the tooth.

It will be understood from the preceding description that the machine is automatic in action, and after it has been started it requires no further attention until that group of blades of the same width and pitch of tooth are re-sharpened. The blade is positively fed through the machine by a double pawl positive feed movement. These two pawls act at the same time, one on each side of the grinding wheel, the one on the right draws the blade in and starts the grinding of the first tooth, that on the left draws the blade clear of the grinding wheel and discharges it. Where teeth are broken out this double pawl positive movement permits of a continuous feed of the blade, and this movement is a positive method of evenly spacing all teeth.

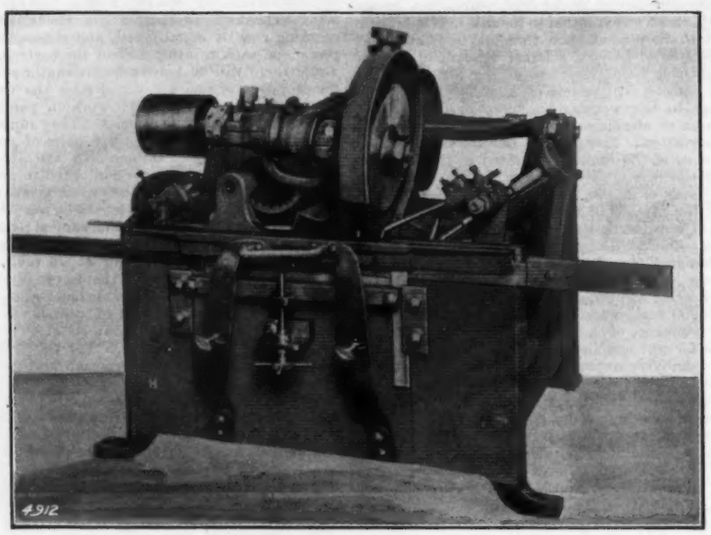
There is an adjustment on the front of the machine for raising the blade in the vice, thereby permitting a slightly heavier cut to be taken without changing the other adjustments. This adjustment is also used in case of a blade having its back warped, through tempering, higher in the middle than at the ends. All adjustments are provided with lock nuts.

One wheel will re-sharpen 200 to 300 blades when taking an average cut on 18-in. blades. The space occupied is 22 in. by 24 in. The weight is 188 lb., and 260 lb. when packed.

Private Work on Motor Car Construction Prohibited.—The Minister of Munitions gives notice that, from November 15, he prohibits until further notice, any person, firm or company engaged in the manufacture or repair of any vehicle designed for mechanical transport or traction, or any part of such vehicle, from carrying out in any factory, workshop, or other premises, without a permit issued under the authority of the Admiralty, the Army Council, or the Minister of Munitions, any work consisting in the manufacture, assembling or erection of any new or unused motor, internal combustion engine, designed or adapted for mechanical traction, or of any new or unused motor cycle, motor chassis, motor wagon or of any tractor or other motor vehicles of any kind propelled by mechanical means, subject, however, to the following exception:—Work required to complete contracts placed by the Admiralty, the War Office, the Minister of Munitions or an allied Government on or before the date of this Order.

AUTOMATIC HACK-SAW BLADE GRINDER.

CONSTRUCTED BY THE WARDWELL MANUFACTURING CO., CLEVELAND, OHIO, U.S.A.



THE INSTITUTION OF CIVIL ENGINEERS.

Address of Sir Maurice Fitzmaurice, C.M.G., M.A., M.A.I., LL.D., President.*

Gentlemen,—It is on account of an unusual and, I think, unprecedented chain of events that I find myself in this chair to-night, after having served only one year as a vice-president of the Institution. Mr. Strain, the senior vice-president last session, found that, owing to heavy and responsible duties in connection with Government war work, he was unable to take up the position of president. Mr. Jebb, a vice-president, retired last session from the Council, carrying with him the affection and regard of all his colleagues, and we had to lament some time ago the death of Mr. Walter Hunter, also a vice-president, and one who for many years was a hard worker in the interests of the Institution.

Some 30 years ago, when a student of the Institution, I was fortunate enough to obtain a Miller Prize. One of the books which I received as part of that prize was "Fragments of Science," by Tyndall. In that book Tyndall gives a description of a visit which he made to the Falls of Niagara in 1872. With the well-known guide, Conroy, he went almost underneath the green waters of the Horseshoe Fall, a spot which at that time no traveller had ever reached. To get to this point several shallow channels, through which water poured torrentially, had to be waded. He passed many of these comparatively easily, but the last channel was more difficult. The guide crossed safely, but Tyndall, when half-way through, was overcome by the rush of water and was swept away, fortunately into the shallow water on the side which he had just left.

The guide exhorted him to try again. Tyndall carefully considered the situation, and wrote, "Prudence was at my elbow whispering dissuasion, but taking everything into account it appeared more immoral to retreat than to proceed."

I have often experienced the same feeling that Tyndall had, but on probably no occasion more strongly, owing to the special circumstances I have already mentioned, than when the presidency of this Institution came my way, and it is only because I feel assured of the goodwill which I have invariably received from members, as well as from my colleagues on the Council, that I am in this chair to-night.

In my case, as in Tyndall's, any success in fording difficult channels has been due more to the guide than to my own exertions. In the early days Sir Benjamin Baker, as master, by instruction and control, and in later days, as friend, by advice and exhortation to proceed, carried me through many of them.

In casting about for a subject on which to address you to-night, I felt at first that it might be of interest to take up the thread of the presidential address in 1883 by the late Sir Joseph Bazalgette, the engineer to the Metropolitan Board of Works. For many years, as engineer to the London County Council, I occupied very much the same position as he did, and I thought it might be useful to look into the development of London from an engineer's point of view during the period which has elapsed since his remarks were made on that subject.

The alterations in London since his time have, of course, been enormous, particularly in the fascinating question of facilities for traffic. At the date mentioned tube railways, motor 'buses and taxicabs had not arrived. The first electric tramways in Great Britain came into operation in that year, but not in London. Unless one compares old and new maps it is difficult to realise the extent of streets widened and new streets constructed during a period of over 30 years. Electric lighting and telephones were only just coming into general use. In other services, such as water supply and drainage, the improvements since Sir Joseph Bazalgette's time have more than followed the increase in population. In fact, on looking into the matter, I came to the conclusion that the subject, if treated as it deserved, was much too vast for a presidential address. I have therefore ventured to content myself with a much smaller subject, and, with some diffidence, I propose to deal in a general way with some very elementary questions which have presented themselves to me in connection with those branches of engineering in which I have been particularly engaged. I am going to say a few words to-night about some of the reasons which at times prevent success in engineering.

There are two kinds of want of success which I propose to consider—that in connection with works and that in individuals. There is a third class which some of us have experienced, namely, want of success in undertakings owing to the financial arrangements coming to grief; but this class, although very disconcerting to engineers, is not so clearly allied to our profession as the two former.

I do not suppose there are any engineers in this room who have carried out undertakings of any extent who have not had, at some time or other, to lament failure or accident in connection with at least some part of their works. For many years I was fortunate enough to be engaged by some of those great engineers whose portraits we see surrounding us, and I cannot recollect any large undertaking which has not at times caused my chief considerable anxiety owing to accident on some portion of the works, or from alteration in design having to be made on account of unforeseen causes. Since I have been carrying out works on my own responsibility I have found a similar state of affairs, and I believe all engineers have from time to time experiences of a like kind.

I am not now speaking of great calamities or disasters such as the failure of the first Quebec Bridge, the first attempt at constructing the Panama Canal, the failure of the old Tay Bridge, that of the first attempt at constructing the Hudson Tunnel, or the complete failure of some reservoir dams. I am referring to those misfortunes which happen more or less on all works of engineering construction.

Although very often not of great magnitude, they cause the engineer, the contractor and client great anxiety and disappointment. The engineer in the case of accident causing loss of life, even although it may be in connection with temporary works for which he is not directly responsible, feels it very keenly, and probably thinks he might have taken, or caused to be taken, some precautions which would have prevented it. Although even a serious accident on works may not entail any extra cost to the engineer's client, it may necessitate such an addition to the time of construction as will seriously dislocate arrangements made for the use of the works, and may in that way be a cause of serious financial loss.

The necessity for alteration of design, or part of design, owing to unforeseen difficulties, is generally a matter

* Delivered on Tuesday, November 7, 1916.

which causes much anxious thought and trouble to engineer and client. Unfortunately, alteration in design is generally accompanied by increased cost and time. In exceptional cases unforeseen difficulties may necessitate abandonment of the work.

The question arises, are engineers as a rule too optimistic in designing their work and in their estimates of time and cost? This question, however, only deals partially with the class of failures I am considering, and before going further I want to clear the ground in connection with one important point.

Works of any size are generally carried out by contract, and the contractor employed has a very important bearing on the question. Probably every engineer would like to choose as contractor for any work which he has to undertake that firm which has previously carried out similar work for himself, or for engineers he knows. This course is, however, one which cannot be adopted, except in a few special cases, owing to obvious reasons.

As is well known, there are two ways of obtaining contractors for works, either by open tender or by asking selected firms to tender. In the first case it is generally understood that it is quite allowable not to accept the lowest tender if the firm has not the necessary experience and standing. There are, however, very often considerable difficulties in rejecting low tenders of unsuitable firms, and explanations to clients are often difficult. I have had experience of a firm tendering for work approximating in value to one million sterling who had no experience of the class of work tendered for, but whose financial and other references were good. Fortunately the tender was passed over. Later on, when the same firm obtained a small contract for somewhat similar work, amounting to about 35,000*l.*, failure took place before the work was two-thirds completed. I only mention this as an example of some of the difficulties which arise in open tendering. It is often very difficult to judge of the financial position and the capabilities of a firm of which one personally has no knowledge. Sometimes those who are given as financial and general references seem to rather more than stretch a point in favour of the firm inquired about, or the answers given are so vague as to be useless.

It might be considered that all difficulties could be avoided by asking selected firms to tender, and in such cases it is generally understood that the lowest tender will be accepted. The procedure is, however, often not satisfactory. It frequently happens that the client wishes to include in the selected list the name of a firm who has carried out to his knowledge some work in a satisfactory way, although of quite a different character to that being dealt with at the time. This is often the cause of great trouble to client, engineer and contractor.

We all know contractors whom we would cheerfully accept without any question of reference, firms who at an early stage of the work recognise the necessity of a good staff and of providing all necessary plant and who know that the initial cost thereby incurred is more than regained by the facilities obtained in carrying out the work and by the saving resulting from curtailment in time of construction. It is probably due to the well-deserved profits made by such contractors that other firms without the necessary capital or experience are frequently tempted to tender for work which they are not capable of carrying out with satisfaction to the engineer or his client, or with profit to themselves.

It must not, however, be assumed that I am favouring in all cases the employment of the large contractors. I have had considerable experience with contractors in quite a small way of business who carry out the smaller contracts entrusted to them in a thoroughly satisfactory way, especially when they have laid themselves out for only one or two classes of work, when the principal can give personal attention to the matter, and when they resist the temptation to embark on undertakings beyond their capacity. Some of my most pleasant experiences in engineering work have been with such firms.

I do not know any more unpleasant position, both for contractor and engineer, than when it is evident that a contract is being carried out at a loss. In such cases the contractor, on the one hand, may be forced to carry out the work in a slow and unsatisfactory way, and the engineer, on the other hand, feels that he cannot well press the contractor to spend more money on plant and staff.

I have very shortly mentioned these difficulties with contracts, as they are a source of real trouble, but I think I ought at the same time to acknowledge the great help which engineers obtain from many contractors. I consider that one of the most pleasant features of our profession in this country is the friendly and helpful feeling which generally exists between engineers and contractors. This is only to be expected when we know that many contractors and a large number of their assistants are connected with this Institution.

I now come back to the question whether engineers as a rule are too optimistic in designing their work, and in their estimates of cost and time. On full consideration of the matter I am inclined to think that we must sometimes plead guilty to this charge, although the optimistic view and under-estimates of cost and time are not always willingly arrived at. I do not know whether my experience on this point is the same as that of other engineers.

I am well aware that even in works where all the details have been worked out with the greatest care, where unit prices have been carefully scrutinised, where the different stages of the work have been well thought out, where all possible local information has been obtained, that even then it is necessary to provide a sum of money over and above the detailed estimate to meet any contingencies which may arise, and to make some addition to the estimated time for construction. In some cases, when adopting this course, I have been met with the statement, particularly when dealing with some Government or municipal authorities, "You surely, if the design has been properly gone into, do not require that large sum of money for contingencies"; or, "Surely you can cut something off the estimate for time of construction." One then explains the reason of money for contingencies and the added time for construction. After some discussion the client says, "Well, what it comes to is that if everything goes well the contingency money might be materially decreased and the time for construction reduced, and I would prefer that we took the risk of cutting both down." The engineer knows from experience that such a course is not wise, and that if things do not go right the conversation will probably be forgotten, but very reluctantly finds himself forced in some cases to reduce his estimate of money and time.

What are the reasons why engineers frequently find that their most carefully made estimates of both cost and time are exceeded? The principal reason is, I think, given by the hackneyed but true phrase which we often hear, that engineering is not an exact science. We are continually finding out more about the forces of nature, but as long as the world exists we shall not find out sufficient to enable us to make exact estimates of time and cost, and guarantee works against accidents.

What, shortly, are the principal matters which cause us trouble? The first one, in my opinion, is the small knowledge we are able to obtain of the conditions which exist below the surface of the earth on which everything has to be founded; secondly, the risk which it is necessary to undertake as regards conditions of weather while works are being carried out; and, thirdly, the varying quality of many of the materials we have to deal with. There is a fourth matter, which affects contractors more than engineers, namely, the difficulty of estimating the cost of materials and rates of wages for a long time ahead. This last also substantially affects engineers' estimates when there is a long interval between the time when the estimates are made and that when tenders are received.

As regards the first of these matters, we, in most cases, try to obtain all information possible about the nature of the ground we have to deal with by making borings. It is commonplace to remark that the information obtained from borings is not always reliable, particularly when the ground is of a variable character. It is true that with certain classes of boring machinery, particularly when in rock, we can obtain cores which give information of great value. In many cases, however, it is very difficult to form a just estimation of the ground when the material has to be broken up by the ordinary drill before being brought to the surface. After all information has been obtained by borings, the fact remains that all we have is a rough idea of the nature of the ground at the exact spot where the boring has been made. In many cases, if one goes 50 ft. north, south, east or west, very different information is obtained. I am sure we all have had experience of being deceived by borings. I know of a recent case where a series of borings was put down for a wharf wall at short intervals on the line of the wall, both back and front, and what was considered to be the level of solid clay was established. As the work proceeded, however, it was found that deep pockets of mud, going to a great depth, existed between some of the borings. There have been cases of railway cuttings where the borings made to disclose the level of the rock unfortunately went into pockets of soft stuff, and I have known one case of that kind where the cost of a very large cutting eventually came to more than double the estimated cost. My partner, Sir William Matthews, when recently referring at this institution to borings put down with the greatest care for the outer barrier, Hodbarrow, said, "If the engineers had purposely placed the borings so as to deceive the contractors with regard to the level of the clay bed, he did not think they could have placed them in better positions."

Such cases could be multiplied at will, and it is quite obvious that borings cannot be made at such close intervals as will disclose, as far as borings can, the nature of all the ground which has to be dealt with.

Then there is the important point that even if by borings the nature of the ground be disclosed, we obtain very little information as regards the quantity of water which may be met with, the dealing with which may be a very important item, both in the cost and time of the undertaking. I was recently pressed very hard by a client to state from borings whether it were possible to construct a graving dock on a certain site. I knew from the borings that water was found all over the site, and although the levels and character of the water did not help me much, it seemed more than possible that there might be direct connection with a large adjacent expanse of water. I had to say that I was unable to answer the question, and that the only way I could suggest to obtain an answer was to sink a shaft for 50 ft. down from the surface of the ground and find what pumping power was necessary, taking also careful notes of the material found as the shaft was sunk and the effect, if any, of the pumping on the adjacent ground. My last information was that a very large number of pumps had been employed, that the shaft had been got down about 25 ft., and that it was not proposed to continue the experiment.

Another matter which it is very difficult to determine by borings is what effect the pressure of the ground may have on the works which it is proposed to construct or what safe foundation pressures can be adopted. We have recently had an important discussion in this Institution on earth pressure, and suggestions were made, after some experiments had been carried out, that the old formulæ for earth pressure might with advantage be revised. The experiments referred to were not on a large enough scale to enable any definite conclusion to be arrived at, but discussion showed that there were different views on the best method of calculating the pressure of a soft material of a more or less uniform character. When there are real differences of opinion on theory, and when there may be considerable local variation in the character of the material to be dealt with, it is easy to imagine the difficulty of accurate appreciation of the strength required for underground works, when the only data afforded by borings arrive in a crushed-up state through a comparatively small tube. Long experience in such cases is the principal base to work from, but even then considerable latitude is left to the personal factor or even to the imagination of the engineer.

There have been cases where borings have been very carelessly and inaccurately made and wrongly described, and there is nothing which brings more trouble in its train. I have in mind borings for a very important work, made by the client and supplied to the engineer, where the information supposed to come from the borings proved to be partly of an imaginative character. Fortunately such cases are of rare occurrence, as engineers generally have borings made under their own control, and recognise the necessity of having a thoroughly reliable assistant continually in charge of the work.

In some cases there are such great difficulties in putting down borings that hope of information from this course must be abandoned. We can sometimes get help by putting them down outside the site, and geologists who have studied the district can give great assistance. We cannot, however, be certain. It was mentioned in the paper read here on the Assouan Dam that it was not possible to obtain borings where the line of the dam crossed the three summer channels of the Nile, on the edge of the First Cataract, owing to the rush of water. It was assumed that in the bed of these channels, which were very deep, all the soft granite had been eroded and that the river was flowing on solid rock. This view seemed reasonable, particularly when it was known that the sides of the channels, as far as they could be examined, were good granite. When the channels were closed off, one by one, by temporary dams, it was, however, found that there were very great depths of decomposed granite at the bottom of the channels. The cost of the additional excavation and masonry was very great, but fortunately, owing to an exceptionally low and late Nile flood, the time of completion of the work was not delayed.

Another case I might mention where borings were not possible was that portion of the Rotherhithe Tunnel under the River Thames. The line of tunnel passed in front of the entrance to the London Docks on one side and the Surrey Commercial Docks on the other side of the river, and owing to the shipping entering and leaving the docks it was not possible to make borings. The only information as regards strata in the river length given to those tendering for the work was that obtained by dredging some comparatively shallow holes in the river bed near the line of the work. There is considerable variation in the bed of the Thames, even in comparatively short distances, and the contractor, as a preliminary operation, very wisely drove a small pilot tunnel near the top of the large tunnel right across the river so as to obtain information, and incidentally it was also useful for other purposes.

In both these cases, which are not isolated instances and are only mentioned as they come within my own knowledge, the estimates of cost and time had to be made on imperfect information, but the best which could be obtained.

I might dilate at much greater length over the pitfalls open to engineers in connection with the want of knowledge of what is below the surface of the earth. I might, for instance, take up some of your time in considering mining or oil enterprises. The details of such works are, however, beyond my personal knowledge, but those who are connected with them know well how often disappointments occur. I have, however, probably dealt sufficiently with this point to show how far removed from an exact science are those works which have, in whole or in part, to be carried out below ground level.

There are other causes which prevent engineers from obtaining exact results, and the war of the elements is very real to them. Many an engineer who has been carrying out harbour works stands helpless and dismayed on his works when an exceptionally heavy storm comes at a specially critical stage of construction, and when the work of months may have vanished in a few hours. It is no consolation to him to know that the contractor standing beside him may have to bear the money loss occasioned by such damage, and it may be less consolation if he knows that on returning from their gloomy inspection he and the contractor will be closely examining in different offices the liability clauses of the contract to make sure of their exact meaning.

Such a picture, to a greater or less degree, is not uncommon on works of this class, as it is quite evident one cannot anticipate their construction without the occurrence of heavy gales, and cannot expect unfinished work to be in a condition to meet such storms without damage. It is unnecessary to refer to damage from the same cause to floating plant, the loss of which is generally a very serious matter.

It is not, however, only unfinished works which suffer. We can probably all bring to mind finished works of the same class which have stood for years and have eventually been overcome by storms of exceptional fury. In some cases failures of such completed works are not due to any initial mistake in design, but are owing to the fact that the inevitable ravages of storms for many years have not been dealt with as they occur, and that in fact maintenance works have been conspicuous by their absence.

Of course harbour works are not the only ones which have to lament the occurrence of exceptional storms during construction. They often cause considerable

damage to incompleted steel work, such as bridges and roofs, and in fact they take their toll from time to time from all works.

The effect of heavy and continuous rain has been brought before us not so long ago by the great damage done in Paris and other places along the Seine. Nearer home, there are very few years when engineers and others have not to lament destruction by floods on a smaller scale in the Thames Valley and other places, a subject which was referred to by Mr. Ross in his address last year. It is in tropical countries, however, that the greatest havoc is caused by rain. I have recently come across great damage to railways in the tropics, and extraordinary and destructive floodings in the neighbourhood of Colombo.

Even in countries like Upper Egypt, which are supposed to be, and practically are, rainless, I have seen very long lengths of railway banks completely washed away by one of those rainstorms, which are very few and far between.

In some countries, where exceptional cold is experienced, the after-effects of continuous frosts have to be fully allowed for in engineering works, both in estimates of cost and time. When I was engaged on the construction of a dock in Canada many years ago great efforts were made in the early winter to get the dock walls up to such a level as would prevent them from being covered by the material from the slopes at the back of the walls, which was sure to come away in the spring. Although it was thought we had been successful in raising the walls to the necessary height, it was not until June in the following summer that we succeeded in clearing away all the material which covered them. Extremes of temperature also often cause considerable difficulty as regards expansion and contraction in engineering works, and I have on more than one occasion experienced some unpleasant results therefrom.

There are other matters affecting not only the estimates of cost and time, but also the utility of engineering works, which are due to the impossibility of being able to arrive at exact conclusions on many points which arise. In the case, for instance, of a harbour constructed on an open coast, where it is often necessary to enclose a large area of the sea, there are many questions the solution of which can only be dealt with as the work proceeds. It may be quite possible definitely to design the character of the works enclosing the harbour, to calculate roughly the velocity of the tidal water entering or leaving the harbour through an opening or openings of certain widths; but in many cases it is extremely difficult to judge what currents will be set up outside the harbour by the intrusion into the sea of such works, or the amount of deposit which may be expected in the harbour. A careful survey of the coast and sea bed for a considerable distance on each side of the proposed works, a study of all existing currents and tidal effects in the locality, the collection of information from pilots and others who are accustomed to the navigation of the coast, the investigation of what has happened in any adjacent harbour or one situated in a similar position, are all of great help. After all this has been done, there are, however, very few engineers who, when there is a considerable range of tide, would care to state the character or velocity of new currents which may be formed near the entrances, or the amount of deposit which may take place in the harbour.

Naturally it is advisable to keep openings as small as possible consistent with safe and easy navigation, so as to reduce wave disturbance in the harbour, and an engineer will therefore probably not fix the width of openings, nor the exact position of the entrance works, until information about currents has developed as the the work proceeds.

Again, in harbour works on some coasts where sand-banks vary from time to time, few engineers find that works can be carried out exactly as originally designed. It is nearly always found that as the works proceed very considerable variations occur in the positions of shoals and channels, which necessitate modification in design.

There is, again, the perennial question of the *actual* stresses occurring in masonry dams. Some time ago this question was fully debated before the Institution, and many experiments in connection therewith on many materials, except masonry and concrete, have been made. We still, however, know very little more than that certain dams designed on certain definite lines have been successful and that others have failed.

We may, again, consider the question of the improvement of rivers, and the many intricate questions which arise in connection therewith. As one of the members of this Institution has very wisely stated, it is necessary for one to live for years with a river before all its idiosyncrasies can be mastered. It, is no doubt, comparatively easy to come to a conclusion on some matters which may obviously require to be dealt with, but dealing with an important river as a whole on a large scale probably requires more experience, study, and careful survey of all the natural features than any other work which an engineer has to deal with.

There is another class of work on which I have seen a good deal of time and money lost, namely, the drainage of low-lying bog lands. I remember one case of a large low-lying area near a river, and surrounded by higher bog land, where drainage operations were undertaken on a large scale, and where what might be mistaken for canals were cut through the area. After some years these canals disappeared, and the bog returned to its natural state. Whether such failure was due to the drains so disturbing the equilibrium of the surrounding country as to cause bog-slides, I do not know. It is possible that a larger number of smaller drains might have been successful; or that if the larger drains had only been gradually deepened over a long period, allowing the ground a chance of consolidating, a more satisfactory result might have been attained. I made no investigation of the matter, but after knowing what happened, one can wisely say it would have been well to make an experiment on a much smaller scale to begin with.

Some time ago my attention was drawn to the fact that it had been necessary, after some 10 years, to renew a long length of heavy hardwood wharf owing to ravages of toredo. Just above the wharf, and apparently under the same conditions, the piers of a bridge constructed of the same kind of timber, and which had been built 40 years previously, appeared to be quite sound. This was a case where the engineer who constructed the wharf commenced the work after full investigation, and where the probability of a long life for the wharf was, one would imagine, almost certain. I was not at the time given any definite reason for the difference in the life of the timber at the two places. I was not able to investigate it, and I am doubtful whether any investigation at that time would have disclosed a satisfactory explanation.

Even in steel bridge work we have not as much knowledge about the actual stresses which occur as is generally supposed. The actual effect of rolling load on bridges has been considered here recently. I do not think it increased our knowledge very much, and there certainly was considerable difference of opinion. In the different members of very large bridges questions arise on which engineers have to come to a decision, but such questions as initial stresses in materials, secondary stresses due to distortion, and sometimes the varying stresses due to erection, are very difficult to tackle with any confidence of arriving at exact results.

A cause of occasional failure in temporary works is due to the fact that engineers and contractors sometimes take deliberate and justifiable risks in connection with such works. If I may again refer to the Assouan Dam, it will give an example of a case where risk was deliberately taken in connection with some temporary works, and where failure resulted. In the construction of this work it was necessary to close the deep summer channels of the Nile by temporary dams of stone and sand. The time required for the construction of these temporary dams was considerable, and the time between one Nile flood and the succeeding one had to be used to the utmost advantage to get in the foundation for the permanent work and to raise the masonry above flood level. It would have given considerably more working time for the permanent work if it had been possible to construct one of the temporary stone dams previous to the Nile flood. There was, however, the question whether such a temporary dam would survive a Nile flood, and the contractor decided to take the risk. As a matter of fact the temporary dam was swept away at an early stage of the flood. The comparatively small cost of the temporary dam, some 10,000*l.*, when compared with the great advantage which would have accrued in the following working season if it had been successful, certainly justified the risk taken.

In many cases of temporary works where risks are taken deliberately, the cost of reconstructing such temporary works, should failure occur, might only be a small portion of the cost involved if the works were constructed in a more solid manner, and in such cases the risk is fully justified.

Perhaps I have said enough in this rather melancholy recital of some of the difficulties which engineers have to contend with to show that the common saying that engineering is not an exact science hardly goes far enough to show how inexact a science it is. Although much of the work of an engineer is based on strictly scientific procedure, it is to a great extent dependent on experiment, experience, and a proper appreciation and balancing of the inexact knowledge available.

It is under these circumstances hardly to be wondered at that estimates of cost and time of construction are not always accurate. Although it is not possible to draw any very close deductions from different tenders submitted by competent contractors for the same work, owing to the fact that one contractor may happen to have in his possession the necessary plant, may have some special facilities in a certain locality, or may have a particular reason for wishing to keep some of his staff together, still the great diversity in the amounts of tenders received from capable and experienced contractors, after making allowance for these matters, is only a very practical confirmation of the fact that exact estimates of time and cost are impossible.

The difficulties I have mentioned, and many others, are, however, the reason why our profession is such an extremely interesting one. New unforeseen difficulties turn up every day, and new methods are being continually found out for dealing with them. Engineering works, after all, have to be carried out, and engineers and contractors have to design and construct them to the best of their ability. It is difficult to make any suggestions to facilitate our work, but it has occurred to me on more than one occasion that our brother engineers on the other side of the Atlantic devote more time than we do to preliminary work and studies, particularly in the case of large undertakings. They appear in some cases to have taught their clients that time and money spent on very full investigation and preliminary studies give a very good return on the expenditure. The Governments of Canada and the United States are also not averse to collecting information about rainfall, river discharges and other matters, which information is at the disposal of those who wish to avail themselves of it. If we could prevail on our clients and on our Government to take similar views, they would also find that the money was not wasted. We are, however, as things stand, dependent to a great extent on experience and private investigation and experiment for the success of many of our works. We ought not, at the same time, to forget the great obligations which we engineers are frequently under to chemists, geologists, metallurgists, meteorologists and others, for the great help which they ungrudgingly give us.

I hope, however, that the Government "Scheme for the Organisation and Development of Scientific and Industrial Research," which has recently come into existence and which has already made a grant to this Institution for research work, may be a real help to engineers. The scheme in its main features is one conceived on broad and patriotic lines, which may lead to results even greater than were anticipated by those who framed it. As far as I know, the detailed arrangements under which it will be administered have not as yet been definitely laid down. Some, but not all, of the industries which may expect help are at the present time so engaged with war work that it is not possible for those controlling them to consider fully, much less to carry out, useful research work. Such work, to be of real value, must be undertaken in consultation with the different industries. It is, however, important that some definite lines for the working of the Government scheme should be laid down at an early date. I hope and believe that it may be developed on such broad, liberal and generous lines as will command general confidence. If worked on such lines the scheme will be of great value. "A great empire and little minds go ill together."

I mentioned at the commencement of these remarks the want of success of individuals. It may seem out of place to refer at this time and in this Institution to such a subject when practically all the members of fighting age are serving either in the Navy or Army, and when all those who have passed that age are lending a hand to the country in some other way. If the willing, and more than willing, anxiety to help in what has been called an engineer's war is a measure of individual success, then the members of this Institution have closely attained to it. We know that over 2,000 of our members, out of a total roll of about 9,000, are serving in the fighting forces, and that we have up to date to mourn the loss of nearly 150 members who have made the great sacrifice of their lives.

The time will come, however, when we must settle down again to our everyday duties, and therefore I venture to say a few words on the question of want of success in individuals. All of us, no doubt, on many occasions during our lives have made mistakes which, with a little reflection, we might have avoided. We have often bought our experience dearly. We probably realise that in some cases there was very little margin between success and failure. In looking back, however, over the great number of engineers whom I have come across on works and in offices, I cannot bring to mind any case of a hard worker who has really failed. It is true that all of them have not arrived at commanding and independent positions, but, then, all men have not the ambition, or wish, or capacity, for such positions. The attainment of such a place might possibly mean failure for some of them, and they prefer to retain the confidence and respect of their employers in the secondary posts, and in doing so they probably have a less anxious and a happier life. I know of some engineers who have not attained to high positions, but who could be sent to take charge of works, with the knowledge that every stage of the work will be carefully and continuously inspected by them, and that if any difficulties arise they will recognise them, and at once report to their chief fully and clearly about them. Such men are invaluable.

There are, however, also a great number of engineers who begin their professional work with the hope and determination of getting to the top rung of the ladder, or at all events making a good fight for it. They realise that the time will come when the seats around this table will be filled by those who are now the younger members, and they want to be there. The roll of this Institution, I am glad to say, is formed of men drawn from all classes of society. I consider that there has been in recent years some improvement in general education which tends to give capable boys the chance of taking up the profession of engineering when they have an inclination in that direction. Very much more, however, might be done in this connection. As far as my knowledge goes, the facilities for the preliminary education of engineers in Canada, Australia, New Zealand and the United States are in some ways greater than in this country, particularly as regards imparting some very necessary commercial knowledge. I believe, also, that in our elementary schools we aim too much at educating everyone up to one standard; we do not pay sufficient attention to the individual, and there is hardly enough opportunity for the better boy to shake himself free from the average. By such method money is wasted in endeavouring to educate a large proportion of boys up to a standard which they can never attain, and which, if they did attain, they would never profit by.

(To be continued.)

SWISS TELEGRAPHS AND THE WAR.—The Swiss telegraphs and telephones during 1915 have been greatly affected by the war, as appears from the recent official report. The international telegraph traffic, with 3,621,945 telegrams, shows an increase of 2.02 per cent., whereas the aggregate telegraph traffic, with 5,482,985 telegrams, shows a decrease of 13.33 per cent. The foreign telephone traffic, with 1,063 conversations, has receded to a minimum, the decrease, compared with the previous year, amounting to no less than 99.81 per cent., on account of closing of the frontier. The budget for telegraphs and telephones showed an anticipated deficit of 4,413,150 francs, instead of which the actual result was a surplus of 2,885,192 francs, of which 1,068,030 francs came from the telegraphs and 1,817,162 francs from the telephones.

HIGH-PRESSURE AIR-COMPRESSORS.*

By Joseph M. Ford.

(*Continued from page 450.*)

Modern Multi-Stage Compressor Practice.

Comparison with Steam Engines.—The care and consideration which must be given to the question of proportioning a compressor is probably of more importance than that required for, say, steam engine design, in addition to which the engineering practice for the successful construction of compressors must be of the highest order. In the case of a triple marine engine the cylinder clearance volumes are of comparatively small importance, and the arrangement of the engine need not be altered to suit the clearances. Should the distribution of work be less even than as designed, it is only necessary to alter the cut-off in the different cylinders. The work done by the high-pressure cylinder can readily be reduced by cutting off earlier in the medium-pressure cylinder, but in an air compressor reduction of the high-pressure work entails the addition of clearance volume to the high-pressure cylinder, which addition it is usually almost impossible to effect.

Small errors in the calculation of steam engine design have sometimes been corrected by the introduction of packing pieces, or stepped keys in the valve gear, but with a compressor it is rarely possible to correct mistakes. The workmanship must be of the highest class, especially with such details as valves and high-pressure plungers. Piston rings and cylinder bores also call for particular attention.

A noteworthy difference between steam engine and compressor design is that, whereas with the great majority of steam engines the cylinders are double-acting, in high-pressure compressor work they are invariably single-acting in the generally accepted sense of the term. Another difference is the very frequent use of differential pistons, which are rarely met with in steam engines. These points give rise to a large number of possible arrangements of compressor cylinders, a few of which are shown diagrammatically in Figs. 19 to 29.

Cylinder Arrangements.—Fig. 19 shows the most common arrangement of a three-stage compressor. On the down stroke air is drawn into the space marked low pressure through the suction valve, having previously passed through a silencer. On the up stroke this air is compressed, and delivered through the first stage intercooler to the annular space marked intermediate pressure, where, on the next down stroke, the second stage of compression is effected. The air is again cooled in an intercooler before passing to the high-pressure cylinder, where the final compression is carried out. Before the air is delivered to the storage bottles it is customary to pass it through an aftercooler (consisting usually of a submerged pipe), in order that the air in bottles shall not becomes unduly heated. This compressor arrangement is largely adopted on Diesel engines, as well as for independent plants, on account of its comparative simplicity and compactness, but it has several disadvantages.

To examine or renew low-pressure or intermediate-pressure piston rings it is generally necessary to lift the whole piston and connecting rod up through the cylinders before the gudgeon pin can be removed, which in some cases, such as in submarine engines, is an undesirable feature on account of the limited headroom usually available. It may also be noted that the low-pressure and intermediate-pressure work is all done in the same cylinder, as it were, so that more heat has to pass through the cylinder walls to the jacket than would be the case were an entirely separate cylinder devoted to each stage of compression. This, however, in practice is not of much moment.

Fig. 20 shows a small two-crank machine suitable for a motor-driven plant. With this type of machine the working parts are in constant thrust. A modification of this last arrangement is shown in Fig. 21, where both lines are driven by the same crank. This "V" compressor has been used on several marine Diesel engines, where the effect of the uneven turning moment resulting from this design is of but slight importance. It may be added that the angle of the "V" is usually somewhat less than that shown diagrammatically in the figure.

A curious adaptation of the type shown in Fig. 19 is given in Fig. 22. This arrangement, although expensive, has been used on some of the largest high-speed Diesel engines yet constructed, and is very satisfactory in operation. Instead of employing a single compressor, two entirely separate small machines are used, actuated from the ends of a rocking lever driven from the crank shaft by means of a single connecting rod.

A great advantage gained is a reduction in the size of cylinders necessary, which results in a marked improvement in the cooling and reliability. In addition, the turning moment of the combination is good, whilst the side thrust on the pistons resulting from the obliquity of the connecting rod in the usual design is, in this case, almost entirely absent. Another minor point to which attention may be directed is, that if a compressor valve breaks on, say, the starboard engine in a ship with this arrangement, only 25 per cent. of the main engine air supply is stopped, instead of half, as would be the case were each main engine fitted with a single compressor. As a result, it is quite likely that it would be found possible to carry on without running a big auxiliary compressor, which in many cases, being motor driven, entails the operation of a large generator set.

Fig. 23 shows the arrangement occasionally adopted for Diesel engine work. Its obvious feature is its simplicity.

An arrangement which has been employed in one or two instances is shown diagrammatically in Fig. 24. Here the high-pressure stage is entirely separate from the other cylinders, and is driven by means of rocking levers. Accessibility is a feature of this design. To remove the intermediate-pressure piston it is only necessary to lift the intermediate-pressure cylinder cover and take off the nut securing the piston to the rod. By lifting the intermediate-pressure cylinder a little, it will now be a simple matter to withdraw the low-pressure piston. The high-pressure piston is easily withdrawn by putting the crank on top centre and uncoupling the link between the levers and piston. Note that the first stage of compression is effected on the under side of the low-pressure piston. This means that the heat from the intermediate pressure is well removed from the heat of the low pressure, so that the cooling is more efficient. The air in the space between the low-pressure and intermediate-pressure pistons is simply compressed on the up stroke, and re-expands on the down stroke—a relief valve being provided to guard against excessive pressure due to piston ring leakage.

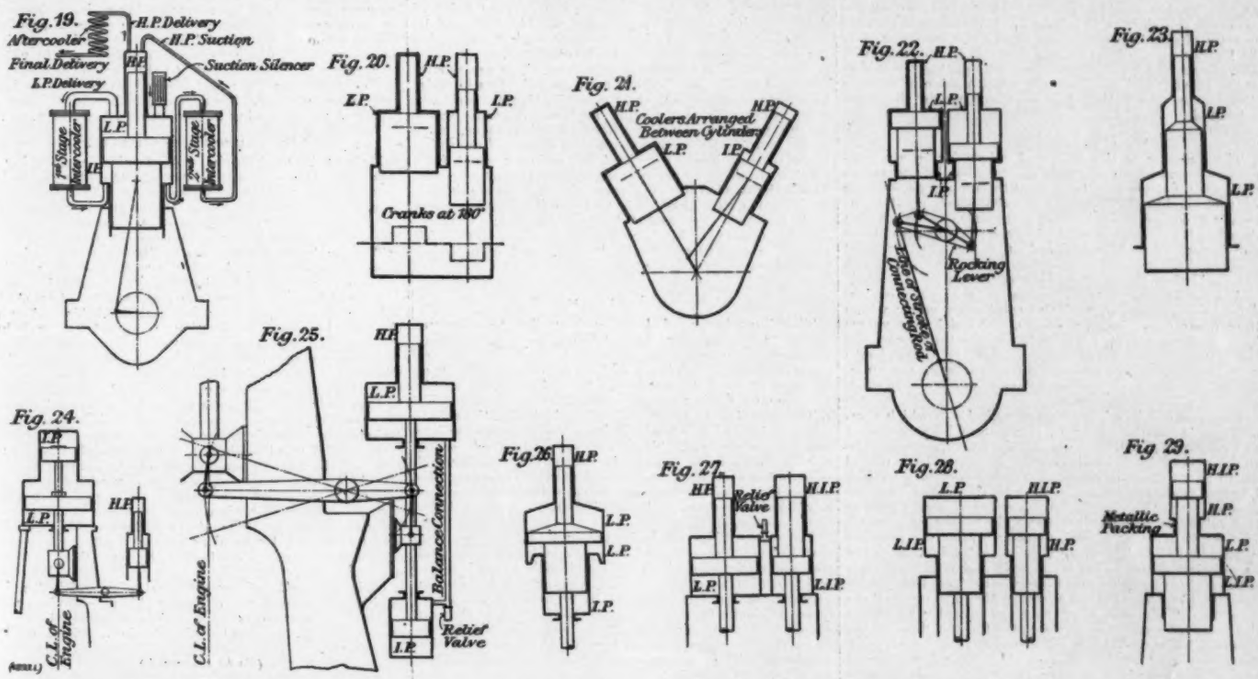
Fig. 25 gives another arrangement of compressor suitable for a Diesel engine, where the air displaced by the idle side of the low-pressure piston is passed to the idle side of the intermediate-pressure piston in a similar manner to the previous case.

In the arrangement shown in Fig. 26 each side of the large piston does a part of the first stage of compression, whilst the second stage is effected in a cylinder at the bottom, as shown. This necessitates the use of a gland subjected to a pressure of perhaps 300 lbs. per square inch as well as a high temperature, but this is of minor importance. The up and down loads are more nearly equal than is the case with the usual arrangement, and, in addition, the maximum crosshead load for a given capacity is reduced as a result of the decreased low-pressure piston diameter. It may be mentioned that this arrangement is adopted in one of the largest compressors yet built for Diesel engine work.

Figs. 27 and 28 show arrangements of four-stage compressors, suitable for torpedo air compressors. The former design necessitates glands, but permits of rather better cooling than the latter, which however has an advantage in that crossheads may be dispensed with if required.

A single-line four-stage arrangement is shown in Fig. 29, but this suffers somewhat from lack of accessibility, although the loads up and down can be equalised, as two stages of compression are carried out on each stroke.

There are other arrangements to suit various conditions as to accessibility, compactness, balance, &c., but those given have been selected as being most representative.



Cylinders and Piston Packing.

The conditions under which compressor pistons run are different from those in a steam cylinder, where there is generally a certain amount of condensation and the water so formed acts as packing in an effective manner. In a compressor a little moisture from the atmosphere is present, but this is generally insufficient to permit of using, for instance, solid piston valves, as sometimes met with in steam practice. Special attention should be given to the question of piston packing, which, however perfect, is useless unless the cylinder bore is machined to within extremely fine limits, the required accuracy being greater the higher the pressure which has to be withstood. In the case of high-pressure cylinders opinion is divided as to the best means of producing the nearest approximation to the perfect bore. Some builders finish the bore by an elaborate system of reamers, and the accuracy and uniformity of the bore so produced leave little to be desired. Other manufacturers pin their faith to grinding methods, and in many cases the bore is lapped out to size. The packing used on high-pressure pistons is varied. For machines such as those used for torpedo charging, which only run intermittently, leather or some patent packing of a similar nature is used. Any slight unevenness in the bore or lack of alignment is taken up easily, and the leakage is very small. The question of temperatures should not be overlooked, for if these are too high, burning of the packing will result, and in some cases, to reduce the possibility of this as far as possible, cylinder lubrication is effected by means of a comparatively copious supply of soap-water, oil being used but sparingly.

In compressors for pressures above 2,500 lb. per square inch it is almost universal to find leather or similar high pressure packing, and very frequently arrangements are

* Paper read before the Greenock Association of Shipbuilders and Engineers.

made for introducing a certain amount of distilled water with the suction air. There are two ways of fixing the packing, one of which is to carry it on the piston, in the same way as piston rings, and the other is to use it in a similar method to that usually adopted with hydraulic machinery—the particular method adopted depending on the arrangement of the compressor.

For a Diesel engine compressor, or any machine which has to run at full load for long periods at a time, leather is not sufficiently durable, and recourse is made to metallic packing, consisting generally of piston rings. These rings are usually made of selected cast iron, and may be of the ordinary "Ramsbottom" or other types. Some builders adopt rather elaborate packing systems for high-pressure pistons which have special properties, such as being adjustable for axial wear and being self-aligning, whilst others use plain cast-iron rings with almost equally good results.

One point in this connection which may be mentioned is that "air packing" should never be adopted with high-pressure pistons, since the high-pressure air forces out the ring against the cylinder wall, and whilst giving a splendid result as far as air-tightness is concerned, increases the wear of the cylinder. Occasionally metallic packing is used in a type of gland, with, in some cases, satisfactory results. The packing may be of the manufactured ring form, or may be shredded white metal and graphite.

Regarding the other cylinders of the compressor, equal attention should be paid to the bores as with the high-pressure cylinder. The piston packing adopted consists usually of cast-iron rings, although some manufacturers fit leather or similar packing throughout the machine. For glands under air pressure, metallic packing is preferable, as the majority of the usual packings quickly deteriorate under the dry heat to which they are subjected.

Valves.

The question of the design of valves for an air compressor is one which demands careful thought and attention, for no other part is so vital to the proper working of the machine. The type of valve used in all high-pressure compressors is the automatic valve, which depends for its action on a difference of pressure above and below it, and is not actuated by any external means. This appears in countless forms, but of few can it be said that they are entirely satisfactory.

Automatic valves are essentially of a more or less delicate construction, and the conditions under which they operate are usually severe. The delivery valves have to pass air at very high temperatures, and the heat, unlike that in a steam engine, is a dry heat; whilst in a high-speed machine running at, say, 450 r.p.m. the valves have to lift and seat themselves in a very short space of time.

For example, in a low-pressure cylinder in which compression is carried to 80 lb. per square inch gauge, at 450 r.p.m. the delivery valves have to open, pass the air, and completely seat themselves again in a period which is actually less than one-sixtieth part of a second. In order that this operation shall be successfully accomplished, either a powerful spring must be used to reseat the valve, or else the lift must be exceedingly small. The result of using a strong spring is that the pressure required to open the valve is excessive, and the hammering of the valve on its seat under the influence of the spring results in very rapid wear. The alternative, namely, the adoption of a small lift, means that the diameter of the seat must be large in order to obtain the requisite area through the valve for the flow of air. It may be stated that velocities in practice through the valve may be 130 ft. per second for low-pressure valves, and may be 250 ft. per second for high-pressure valves.

If the diameter of the seat is increased over that sufficient with a larger lift, the leakage is increased, owing to the larger circumference of the contact circle; and, moreover, since a large valve is more liable to heat distortion than a small one, the possibilities of leakage are still greater.

Whatever the diameter of the valve, the weight should in every case be brought to the minimum. This reduces the inertia forces, and thereby the spring strength. Consequently the wear due to hammering and excess pressure required to open the valve is decreased. The type of valve usually employed for high-pressure work is the thimble valve, which can be used either for suction or delivery, two or more being used per cylinder to obtain the necessary area of flow. The valves proper are usually of nickel steel, and the seats of best quality bronze or gun-metal, although one Diesel engine builder used to fit valves in small compressors with seats of ebony or lignum vitæ. The actual seat should be as narrow as possible, in order that the unbalanced load may be reduced to a minimum.

For moderately high pressures small valves of the well-known plate type are frequently used. The plate is usually of special steel and the seat of bronze. It has been found in practice that this type of valve, at any rate in the larger sizes, is liable to fracture if the lift is too great, so that, in order to obtain sufficient area for the passage of the air and at the same time keep down the diameter, it is necessary to adopt multiple seats and to cut ports in the valve for the exit of a part of the air.

Given suitable conditions, this type of valve when properly designed and made is superior to the thimble or poppet type, especially for the low-pressure stage, but the plates are somewhat unreliable when the temperature is excessive. One advantage over the other type is that carbonisation has very little effect on the working.

A type of valve to which one prominent Continental firm have pinned their faith is the "Gutermuth" valve, which consists essentially of a strip of steel wrapped round a spindle in a similar manner to a clock spring. This has been used with great success in all the stages of Diesel engine compressors up to quite large sizes.

In high-pressure compressor work the valves must be kept in thoroughly good condition, as otherwise a leakage may take place from any stage to a lower one, thus increasing the pressure and temperature attained in the latter. This would upset the balance, and in extreme cases cause a serious breakdown by adding, perhaps, 250 per cent. to the load on the connecting rod bolts. To guard against such contingencies it is of the utmost importance that ample relief valves be fitted to all stages, and however reliable a machine may appear to be, it is dangerous to run with the relief valves out of action.

It is not proposed to deal with mechanically moved valves, as their application to high-pressure compressor work is limited, usually to the low-pressure suction, with perhaps the addition of the intermediate-pressure suction. The great advantage of a mechanical suction valve for the low pressure is that one can ensure that the cylinder is filled with air at atmospheric pressure, instead of at a lower pressure due to the attenuation consequent upon a spring-loaded suction valve. If this mechanical valve is arranged in the piston itself, as is done in some designs, the cylinder clearance volume can be appreciably reduced.

The delivery valves are invariably automatic. A valve gear which would adapt itself to the varying point of delivery with different pressures would obviously be somewhat complex. In high pressure work the necessity for this refinement is rather doubtful.

Regarding the disposition of valves, these are usually arranged in the cover of low-pressure cylinders in order to reduce clearance as far as possible, thereby seriously detracting from the cooling surface. Suction valves in the piston are not without disadvantages, since at the end of the suction stroke the inertia of the valve tends to seat it too soon and the cylinder is not fully filled with air. In some cases this arrangement necessitates the suction air being drawn through the crank case. It is argued that this tends to keep the running parts cool, but this is a doubtful advantage when it is remembered that the low-pressure compression starts with air which has been already heated, and is probably charged with oil vapour.

Cooling Arrangements.

The importance of keeping low the temperature within a compressor has already been emphasised. High temperatures are detrimental to the satisfactory operation of the machine, and in addition result in an increase in the work required. Special attention should be given to cooling arrangements.

The best time to effect the cooling is during the actual compression, as this tends to keep the compression low near the isothermal. There are two methods of cooling during compression, namely, jacketing the cylinder and injecting water into the compressor. Regarding the latter, it is necessary to use fresh or distilled water, as any deposit would have harmful results on the cylinder bores, valves, &c.

Jacketing.—This method, although efficacious to a certain point, is only used in a few isolated cases, and the majority of machines are fitted with water jackets, which act in exactly the same way as the jackets on internal combustion engines. In high-speed machines, however, jacketing is of comparatively little value on account of the rate at which heat is generated, and as a result the compression law approximates to the adiabatic. The conditions are sometimes aggravated by a bad arrangement of valves, or thick liner flanges just where the cooling is most wanted, and these points, coupled with bad jacket circulation caused by air locks resulting from faulty design, render the cooling on some machines practically valueless as far as the work done, &c., is concerned. On the other hand, in machines designed with large clearance volumes (the low-pressure cylinder, of course, excepted) the cooling can be considerably improved by using a submerged pipe to conduct the air between the cylinder proper and the valves. This means that there is an increase in the cooling surface, and, moreover, the cooling here can be effected under the best conditions as to conductivity of the walls, &c.

Not only is the air cooled during compression, but it also loses heat during re-expansion, so that the incoming air meets with comparatively cool clearance air, which condition assists in keeping low the initial compression temperature, and thereby reducing the maximum cylinder temperature.

Intercoolers.—In practice, however, as it is impossible to deliver the air directly from one stage to the next in a cool condition, it becomes necessary to resort to intercooling. Between the stages the air is passed over a suitable cooling surface, which abstracts the remaining heat resulting from the compression in the lower stage, and the air enters the next stage cylinder in a cool state, the necessity for which has been previously explained.

Intercoolers may consist of a simple coiled pipe, or may be of the multitubular type—similar to a surface condenser. The coiled pipe type takes up far more space per square foot of cooling surface than the multitubular variety, unless the construction of the machine permits of the coil being placed in the jacket round the cylinders, in which case a very compact arrangement is obtained at little cost. A point with this arrangement which merits attention is the supporting of the coils. When a compressor is running at full load of, say, 1,500 lb. per square inch, a very decided "thump" can be felt on the discharge pipe with each delivery of air, resulting in excessive vibration of the pipe unless carefully stayed. In time, fracture of the pipe results, and if the coil happens to be carrying a high pressure, the effects may be considerable.

Additional protection can be secured by making the coil of thicker gauge pipe, which procedure, within limits, actually improves the cooling for a given bore of tube, on account of the increased external surface.

The construction of tubular intercoolers is along similar lines to that of surface condensers, except that whereas in the latter the tubes are usually secured by ferrules, in the former they are almost invariably expanded at the ends, as the size does not warrant the more elaborate construction. Copper tubes and steel tube plates, which are unusual in condensers, are frequently used in intercoolers, the tubes varying in modern practice from ¾ in. to 1 in. outside diameter. With intercoolers the water is outside and the air flows through the tubes. Multitubular coolers are used for pressures up to about 450 lb. per square inch, and above this the submerged coil type is adopted, as necessitating fewer joints.

Cooling in General.—The cylinders may have jackets cast integrally—which on account of cleaning difficulties is not to be highly recommended—or separate jackets may be used.

The best arrangement is to immerse the whole of the cylinders, valve chests, connecting pipes and intercoolers in a "tank." In other designs there is always present the possibility of air pockets, or the intercoolers taking most of the water and causing the jackets proper to heat, in addition to which the inconvenience of exposed copper pipes at high temperatures is not inconsiderable. In many cases, however, the question of space prohibits the adoption of the "tank" system of cooling, and it is necessary then to jacket connecting pipes and fit valves to regulate the water supply to the various elements.

For aftercoolers, a usual method adopted is to have two concentric tubes, the air passing through the central pipe and water flowing in the annulus between them.

Regulation and Control.

Perhaps in no branch of mechanical engineering is there more scope for control arrangements for regulating output than with compressor work. The subject is extensive, and only an outline can be given of the several methods whereby the output of a compressor may be altered, the speed being maintained constant.

The usual arrangement has for its object the maintenance of a constant delivery pressure, with varying volume output, and consists simply of suitable means for throttling the suction air and thereby altering the volume of air aspired by the machine. The effect of this on the work distribution, temperatures, &c., has already been discussed in the notes on clearance.

Another method of achieving the same object, but which only gives two definite capacities, is to arrange that the stage pressures under normal conditions shall be low, and to provide an auxiliary low-pressure cylinder, so that, when the increased output is desired, this cylinder delivers air as well as the main low-pressure cylinder. A third method is to alter the effective capacities of the various stage cylinders by adding for the time being suitable clearance volume, resulting in less air being dealt with. An advantage of the system is that the correct work distribution may be maintained at the reduced capacity. The above alterations in capacity may be effected by hand or automatically by a system of pneumatic relays controlled by the final delivery pressure.

It is assumed, of course, that the speed remains unaltered, although by changing this it is obvious that regulation can be effected. This method, however, would clearly not be permissible in a Diesel engine compressor.

(To be continued.)

The Japanese Navy.—We read in *The London and China Telegraph* that the floating dock, which was recently brought to Saseho from Taingtao, is now undergoing repairs, which, it is expected, will be completed shortly. It is stated that as soon as the repairs are completed the dock will be sold by tender. Either the Mitsubishi or the Kawasaki Dockyard, it is supposed, will be the purchaser. The battleship Yamashiro, which was built at the Yokosuka Navy Yard and is receiving armament there, is expected to be completed in December next. Of the twelve 14-in. guns, which the warship will carry, 5 guns have been already mounted, and the installing of engines and boilers has already been finished.

A Great Indian Dam.—It will be remembered that a great dam is proposed in the Cauvery, in the province of Mysore, the object being the promotion of irrigation, and an additional electric installation at Sivasamadram. The cost is estimated at 1,687,000*l.*, upon which the Mysore Government expects a return of 5.8 per cent. per annum, with the probability of an eventual increase to twice that amount. From a financial point of view it is considered that there is no doubt that the dam will be a great success. With the dam in its initial stage of construction the Mysore Government was enabled in the last hot season to save upwards of 3,000*l.* The dam, when fully constructed, will be 124 ft. above the river bed and 6,300 ft. in length, with a foundation depth of 20 ft. It will present a convex surface to the water, and will be capable of impounding 41,500,000,000 cubic feet of water. The top of the dam will be corbelled out from 12 ft. to 14 ft.; the bottom width at the base of foundation will be 114 ft. There are 26 under-sluices, which are capable of discharging over 80,000 cubic feet of water in a second. An irrigation canal nearly 100 miles long is proposed to be developed on the northern bank; a feature of this canal will be a subterranean passage through the crest of a hill by means of a tunnel 2½ miles in length.